AD NUMBER
AD249957
LIMITATION CHANGES
TO: **Approved for public release; distribution is unlimited.**
FROM: **Distribution authorized to U.S. Gov't. agencies and their contractors; Administrative/Operational Use; NOV 1960. Other requests shall be referred to Ballistic Research Lab., Aberdeen Proving Ground, MD.**
AUTHORITY
ARL Form 1 dtd 3 Feb 2013

BRL

MEMORANDUM REPORT NO. 1306
NOVEMBER 1960

A MATHEMATICAL FORMULATION FOR ORDVAC COMPUTATION OF THE SINGLE-SHOT KILL PROBABILITIES OF A GENERAL MISSILE VERSUS A GENERAL AIRCRAFT

Anthony D. Stiegler

[redacted]

Department of the Army Project No. 5B03-06-002
Ordnance Management Structure Code No. 5010.11.812

BALLISTIC RESEARCH LABORATORIES

ABERDEEN PROVING GROUND, MARYLAND

ASTIA AVAILABILITY NOTICE

Qualified requestors may obtain copies of this report from ASTIA.

B A L L I S T I C   R E S E A R C H   L A B O R A T O R I E S

MEMORANDUM REPORT NO. 1306

NOVEMBER 1960

A MATHEMATICAL FORMULATION FOR ORDVAC COMPUTATION OF THE SINGLE-SHOT KILL PROBABILITIES OF A GENERAL MISSILE VERSUS A GENERAL AIRCRAFT

Anthony D. Stiegler

Department of the Army Project No. 5B03-06-002
Ordnance Management Structure Code No. 5010.11.812
(Ordnance Research and Development Project No. TB3-0007)

A B E R D E E N   P R O V I N G   G R O U N D,   M A R Y L A N D

TABLE OF CONTENTS

B A L L I S T I C   R E S E A R C H   L A B O R A T O R I E S

MEMORANDUM REPORT NO. 1306

ADStiegler/sec/ebh
Aberdeen Proving Ground, Md.
November 1960

A MATHEMATICAL FORMULATION FOR ORDVAC COMPUTATION OF THE SINGLE-SHOT KILL PROBABILITIES OF A GENERAL MISSILE VERSUS A GENERAL AIRCRAFT

ABSTRACT

This report is an up-dating of BRL Report No. 867. That report gives a description of the physical model and the random number generators used in this report.

The methods of BRL Report No. 867 have become inadequate for the solution of the problem with all the recent modifications and refinements and have been superseded by the methods discussed in this report.

The main body of the report is devoted to a mathematical discussion of the problem and appendices are included for the programming. The equations were formulated by Messrs. De Gray and Stubbs. The following assumptions were made: the missile and target are traveling in straight lines, the rear nape of the cone fuze pattern has been omitted, the azimuth and elevation angles are not necessarily standard for all missiles.

The discussion has been limited to the fixed-angle (cone-type) guided missile fuze, but another fuze (the proximity fuze) is being analyzed and will be reported upon in due course.

INTRODUCTION

The problem is to determine the probability of kill by blast and fragmentation of a general missile against a general target with a computing machine code simulating the real situation. The blast is determined against the aircraft as a whole, while the fragmentation is determined against various vulnerable components of the aircraft (e.g., the pilot, bomb, etc.). In order to make the computing machine code as general as possible four component types have been allowed for and space has been left for six more.

Essentially, the code is composed of three general sections. The first section deals with reading and scaling the input data and computing the elevation and azimuth angles of the missile with respect to the target's co-ordinate system. The second section computes the burst point (i.e., the point at which the warhead will detonate) and the effects of blast. The third section computes the fragmentation kills on the individual components.

Besides the above there are three other sections which vary for each target. These are the combinatorials section, the vulnerable areas section, and the "variable numerators" section. Each of these will be treated in more detail below.

The final section of the code is the output section, which prints out probabilities of kill averaged for the given number of rounds desired. NOTE: A pictorial representation of the mathematical model can be found in BRL Report No. 867.

INPUT

The input section reads in the input and scales it, initializes the code, and computes the elevation and azimuth angles of the missile. The input consists of the following:

Shields (Co-ordinates of ellipsoid center followed by axis lengths)
Vulnerable Component centers (Co-ordinates of each center)

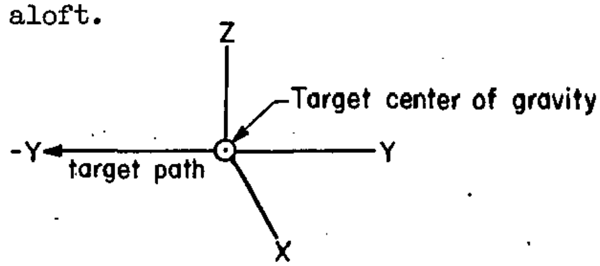
Glitter Points (Co-ordinates of each point)
Blast (Ellipsoids, as above for Shields)
Number of Vulnerable Components
Number of Shield Ellipsoids
Number of Blast Ellipsoids
Number of each specific vulnerable component (Number of Pilots, number of Bombs, etc.)
Fragment spray angles measured from the missile nose
Number of fragments per steradian in each spray
Initial fragment velocity in each spray
Fuzing and guidance errors (Standard Deviations)
Missile Speed (ft/sec.)
Target Speed (ft/sec.)
Total number of rounds to be computed
Fuze half angle (only necessary for fixed angle fuze)
Iteration Center Co-ordinates
Ballistic co-efficients of the fragments in each spray
Fragment mass in each spray
Distribution of Approaches (See Elevation and Azimuth Calculation for full explanation)
Homing Points (Co-ordinates)
Delay Time (sec.)

Variable Numerator Sentinel (See pp 18-19 for explanation). For scaling and location of the above quantities see Appendix A. N.B. The shields, component centers, and glitter points remain static for any one target and are therefore read in only once. Also, all points are given with respect to the target.

ELEVATION AND AZIMUTH CALCULATION

The target is assumed to be moving in a straight line on the Y axis in the -Y direction. The missile is assumed to be approaching the target on a random straight line. The Elevation is defined as the angle between

the missile velocity vector V_M and the XY plane of the target co-ordinate system. The center of the co-ordinate system is the center of gravity of the target and the plus X direction is to port and the plus Z direction aloft.



TARGET CO-ORDINATE SYSTEM

An elevation angle between $+E_1$ degrees and $-E_1$ degrees is computed. This angle is computed as follows:

Choose a uniform random number $0 \leq \rho \leq 1$, and then form the function $1-2\rho_1$, which satisfies

$$-1 \leq 1-2\rho_1 \leq +1 \quad .$$

(Since all angles are in degrees, the degree sign has been omitted in the following discussion.) Multiplying this function by E_1 gives an elevation angle, E, such that:

$$-E_1 \leq E \leq +E_1 \quad .$$

The sine and cosine of E are computed.

The Azimuth angle A is the angle between the missile velocity (V_M) and the YZ plane of the target. In the simulation these A's are randomly computed.

Having a uniform random number ρ such that

$$0 \leq \rho \leq 1$$

form ψ such that $\psi = 1-2\rho$ then $-1 \leq \psi \leq 1$ uniformly.

Now, for the first given percentage form

$$f_1(\rho) = A_1\psi$$

whose limits are

$$- A_1 \leq f_1(\rho) \leq + A_1$$

For the second percentage define

$$f_2(\rho) = \begin{cases} \psi < 0; & (A_2 - A_1)\,\psi - A_1 \\ \psi \geq 0; & (A_2 - A_1)\,\psi + A_1 \end{cases}$$

whose limits are

$$- A_2 \leq f_2(\rho) \leq - A_1$$

and

$$+ A_1 \leq f_2(\rho) \leq + A_2$$

and in general for the ith percentage define $f_i(\rho)$ as

$$f_i(\rho) = \begin{cases} \psi < 0: & (A_i - A_{i-1})\,\psi - A_{i-1} \\ \psi \geq 0: & (A_i - A_{i-1})\,\psi + A_{i-1} \end{cases}$$

provisions will be made for seven (7) distributions of A. The A_i's and the percentages are given. For i = 1, $A_o = 0$. Then, $F_i(\rho) = A$, where A is the azimuth angle.

Compute the sine and cosine of A and then go to the fuzing and blast section.

NOTE: The uniform random number generator is described in BRL Report No. 855.

FUZING AND BLAST

The following description involves two co-ordinate systems, that of the target and that of the missile. The first (X, Y, Z) system has its origin at the center of gravity of the target. The second $(\alpha_1, \alpha_2, \alpha_3)$

system has its origin at the center of gravity of the missile warhead. All data points are given in the X,Y,Z, system (i.e., relative to the target). Both missile and aircraft are traveling a straight course without pitch, yaw, or roll.

Since the solutions of the fuzing equations are more easily obtained with respect to the missile, and all points are given with respect to the target, the points must be mapped into the missile co-ordinate system. Direction cosines of the target, missile, and relative velocity vector are required. The following conventions have been adopted in symbolizing these direction cosines:

ℓ:	The cosines of the angle between the vector and the first axis of the system.
m:	The cosine of the angle between the vector and the second axis of the system.
n:	The cosine of the angle between the vector and the third axis of the system.
Unprimed:	Direction cosines of the target.
Primed:	Direction cosines of the missile.
Double Primed:	Direction cosines of the relative velocity vector.

A subscript defines whether any item is with respect to the target (T) or the missile (M).

Thus there are six sets of direction cosines. These are:

$$(\ell_T, m_T, n_T) \quad (\ell'_T, m'_T, n'_T) \quad (\ell''_T, m''_T, n''_T)$$

$$(\ell_M, m_M, n_M) \quad (\ell'_M, m'_M, n'_M) \quad (\ell''_M, m''_M, n''_M)$$

Each is fully defined by the above conventions.

Since the target is assumed to be traveling in a -Y direction and the missile is assumed to be traveling in a $-\alpha_1$ direction,

$$\ell_T = 0, \quad m_T = -1, \quad n_T = 0$$

$$\ell'_M = 1, \quad m'_M = 0, \quad n'_M = 0$$

The direction cosines of the $\alpha_1, \alpha_2, \alpha_3$ axes with respect to the X,Y,Z axes are:

$$\begin{array}{lll} \lambda_1 = \cos E \sin A & \rho_1 = \cos A & \gamma_1 = - \sin A \sin E \\ \lambda_2 = -\cos E \cos A & \rho_2 = \sin A & \gamma_2 = \cos A \sin E \\ \lambda_3 = \sin E & \rho_3 = 0 & \gamma_3 = \cos E \end{array} \qquad (1)$$

Thus, the other direction cosines are:

$$\begin{array}{ll} \ell'_T = - \cos E \sin A & \ell_M = \cos E \cos A \\ m'_T = \cos E \cos A & m_M = - \sin A \\ n'_T = - \sin E & n_M = - \sin E \cos A \end{array} \qquad (2)$$

and

$$\ell''_M = \frac{|\vec{V}_T| \cos A \cos E + |\vec{V}_M|}{|\vec{V}_R|} \qquad \ell''_T = - \frac{|\vec{V}_M| \cos E \sin A}{|\vec{V}_R|}$$

$$m''_M = - \frac{|\vec{V}_T| \sin A}{|\vec{V}_R|} \qquad m''_T = \frac{|\vec{V}_M| \cos E \cos A + |\vec{V}_T|}{|\vec{V}_R|} \qquad (3)$$

$$n''_M = - \frac{|\vec{V}_T| \cos A \sin E}{|\vec{V}_R|} \qquad n''_T = - \frac{|\vec{V}_M| \sin E}{|\vec{V}_R|}$$

where

$$|\vec{V}_R| = \sqrt{|\vec{V}_T|^2 + |\vec{V}_M|^2 + 2 \vec{V}_M \vec{V}_T \cos A \cos E}$$

Having determined the above direction cosines, choose the first "glitter point". A glitter point is a point on the target which is a good reflector of waves emitted by the fuze in the missile. Now since the glitter point is given with respect to the center of gravity of the

target and the missile actually "homes" or aims at a different point (viz, the geometric center of all the glitter points), subtract the coordinates of this "homing point" H from those of the glitter point GP, thus translating the center of the system from the center of gravity of the aircraft to this homing point. Thus:

$$
\begin{aligned}
X'_{GP} &= X_{GP} - X_H \\
Y'_{GP} &= Y_{GP} - Y_H \\
Z'_{GP} &= Z_{GP} - Z_H
\end{aligned}
\tag{4}
$$

<u>N.B.</u> This homing point varies for each of the three distributions of A and is selected at the time at which A is computed.

We next rotate this glitter point into the missile co-ordinate system with its origin at the target homing point by the equations:

$$
\begin{aligned}
\lambda_1 X'_{GP} + \lambda_2 Y'_{GP} + \lambda_3 Z'_{GP} &= \Delta\alpha_{1GP} \\
\rho_1 X'_{GP} + \rho_2 Y'_{GP} + \rho_3 Z'_{GP} &= \Delta\alpha_{1GP} \\
\gamma_1 X'_{GP} + \gamma_2 Y'_{GP} + \gamma_3 Z'_{GP} &= \Delta\alpha_{3GP}
\end{aligned}
\tag{5}
$$

where the λ's, ρ's, and γ's are defined by equations (1) above.

The path of H (the homing point) goes through a point $(o, \alpha'_2, \alpha'_3)$ when it crosses the $\alpha_2\alpha_3$ plane. The path of GP (the glitter point) goes through a corresponding $(\Delta\alpha_{1GP}, \alpha'_2 + \Delta\alpha_{2GP}, \alpha'_3 + \Delta\alpha_{3GP})$. This second point is not necessarily on the $\alpha_2\alpha_3$ plane. The path of H does not pass through (0,0,0) because of the guidance errors α'_2 and α'_3 which are chosen randomly from a normal distribution. Translating to a co-ordinate system whose center is at the missile warhead center of gravity gives

$$
\begin{aligned}
&\text{(a)} \quad \alpha_{1GP} = \bar{\alpha}_1 + \Delta\alpha_{1GP} \\
&\text{(b)} \quad \alpha_{2GP} = \bar{\alpha}_2 + \Delta\alpha_{2GP} \\
&\text{(c)} \quad \alpha_{3GP} = \bar{\alpha}_3 + \Delta\alpha_{3GP}
\end{aligned}
\tag{6}
$$

where $(\bar{\alpha}_1, \bar{\alpha}_2, \bar{\alpha}_3)$ is the missile warhead center of gravity in the homing point system.

The equation of the line traversed by the glitter point is

$$\frac{\alpha_1 - \alpha_{1GP}}{\alpha_{1GP} - \Delta\alpha_{1GP}} = \frac{\alpha_2 - \alpha_{2GP}}{\alpha_{2GP} - (\alpha_2' + \Delta\alpha_{2GP})} = \frac{\alpha_3 - \alpha_{3GP}}{\alpha_{3GP} - (\alpha_3 + \Delta\alpha_{3GP})} \qquad (7)$$

Substituting equations (6) into equation (7) gives:

$$\frac{\alpha_1 - \alpha_{1GP}}{\bar{\alpha}_1} = \frac{\alpha_2 - \alpha_{2GP}}{\bar{\alpha}_2 - \alpha_2'} = \frac{\alpha_3 - \alpha_{3GP}}{\bar{\alpha}_3 - \alpha_3'} \qquad (7.1)$$

This line has direction numbers

$$P = \bar{\alpha}_1$$

$$Q = \bar{\alpha}_2 - \alpha_2'$$

$$R = \bar{\alpha}_2 - \alpha_3'$$

and direction cosines ℓ_M'', m_M'', n_M'' defined by (3). Then

$$\frac{\ell_M''}{\bar{\alpha}_1} = \frac{m_M''}{\bar{\alpha}_2 - \alpha_2'} = \frac{n_M''}{\bar{\alpha}_3 - \alpha_3'} \qquad (7.2)$$

Solving for $\bar{\alpha}_2$ and $\bar{\alpha}_3$ in terms of $\bar{\alpha}_1$ gives

$$\bar{\alpha}_2 = \alpha_2' + \bar{\alpha}_1 \frac{m_M''}{\ell_M''}$$

$$\bar{\alpha}_3 = \alpha_3' + \bar{\alpha}_1 \frac{n_M''}{\ell_M''} \qquad (7.3)$$

Hence, by virtue of 6(b) and (c):

$$\alpha_{2GP} = \alpha_2' + \frac{m''}{\ell''} \bar{\alpha}_1 + \Delta\alpha_{2GP}$$

$$\alpha_{3GP} = \alpha_3' + \frac{n''}{\ell''} \bar{\alpha}_1 + \Delta\alpha_{3GP} \qquad (8)$$

Substituting for $\bar{\alpha}_1$ in (8) by use of (6) a gives

$$\begin{aligned} \alpha_{2GP} &= A + \alpha_{1GP} \frac{m''_M}{\ell''_M} \\ \alpha_{3GP} &= B + \alpha_{1GP} \frac{h''_M}{\ell''_M} \end{aligned} \qquad (9)$$

where

$$A = \alpha'_2 + \Delta\alpha_{2GP} - \Delta\alpha_{1GP} \frac{m''_M}{\ell''_M}$$

$$B = \alpha'_3 + \Delta\alpha_{3GP} - \Delta\alpha_{1GP} \frac{n''_M}{\ell''_M}$$

these equations (9) give expressions for the glitter point in the α - system with origin at the missile warhead center of gravity.

Now in the solution of the fixed angle guided missile fuze, we have the problem of finding the intersection of a line (the line traversed by the glitter point) and a cone (the fuze pattern of our fuze). The equations of these are:

$$\frac{X - X'_{GP}}{\ell''_M} = \frac{Y - Y'_{GP}}{m''_M} = \frac{Z - Z'_{GP}}{n''_M} \qquad (10)$$

and

$$\alpha_2^2 + \alpha_3^2 = \alpha_1^2 \tan^2 \theta \qquad (11)$$

respectively, where θ is the fuze half-angle, which is given. Here α_1, α_2, α_3, are the coordinates of a typical point on the cone in a system with origin at the missile warhead c of g.

Since equations (8) are equations of the line in the missile coordinate system and the problem is to find the α_{1GP} which satisfies equation (11), we merely substitute equations (8) in equation (11) and solve for α_{1GP}, as follows:

$$\left(A + \alpha_{1GP} \frac{m''_M}{\ell''_M} \right)^2 + \left(B + \alpha_{1GP} \frac{n''_M}{\ell''_M} \right)^2 \tag{12}$$

$$= \alpha_{1GP}^2 \tan^2 \Theta$$

Squaring and collecting terms and algebraically manipulating gives an equation of the form

$$a\alpha_{1GP}^2 + 2b\,\alpha_{1GP} + c = 0 , \tag{13}$$

where

$$a = 1$$

$$b = \frac{\ell''_M \left(Am''_M + Bn''_M\right)}{m''^2_M + n''^2_M - \ell''^2_M \tan^2 \Theta} \tag{14}$$

$$c = \frac{\ell''^2_M \left(A^2 + B^2\right)}{m''^2_M + n''^2_M - \ell''^2_M \tan^2 \Theta}$$

Therefore,

$$\alpha_{1GP} = \frac{-\,2b \pm \sqrt{4b^2 - 4\,ac}}{2\alpha} \tag{15}$$

With a = 1 from equations (14) this becomes

$$\alpha_{1GP} = -\,b \pm \sqrt{b^2 - c} \tag{16}$$

Then substituting in equation (6)

$$\alpha_{1f} = \alpha_{1GP} - \Delta\alpha_{1GP} \tag{17}$$

where α_{1f} is the α_1 co-ordinate of the homing point when the missile would fuze if it only "saw" this glitter point.

We compute equations (4) through (17), inclusive, for all glitter points. Then, the algebraically smallest α_{1f} is chosen and designated α_{1F}.

This α_{1F} is the α_1 co-ordinate of the homing point at the time when the missile actually fuzes. Then

$$\alpha_{1B} = \alpha_{1F} + \epsilon + \ell''_M \; V_R \; D_t$$

and

$$\begin{aligned} \alpha_{2B} &= \alpha''_2 + \alpha_{1B} \frac{m''_M}{\ell''_M} \\ \alpha_{3B} &= \alpha'_3 + \alpha_{1B} \frac{n''_M}{\ell''_M} \end{aligned} \tag{19}$$

where D_t is a given delay time in seconds and ϵ is a normally distributed fuzing error.

This gives the co-ordinates of the homing point at the time of burst in the missile system with center at the missile warhead. Then

$$\begin{aligned} X'_B &= + (\lambda_1 \, \alpha_{1B} + \rho_1 \, \alpha_{2B} + \gamma_1 \, \alpha_{3B}) \\ Y'_B &= + (\lambda_2 \, \alpha_{1B} + \rho_2 \, \alpha_{2B} + \gamma_2 \, \alpha_{3B}) \\ Z'_B &= + (\lambda_3 \, \alpha_{1B} + \rho_2 \, \alpha_{2B} + \gamma_3 \, \alpha_{3B}) \end{aligned} \tag{20}$$

give the co-ordinates of the homing point in the target co-ordinate system with center at the missile warhead. It is necessary to have the co-ordinates of the missile in the target system with center at the homing point. These co-ordinates are the negatives of (20).

But these have the homing point H as center of the co-ordinate system and, therefore, they must be translated back into the system centered at the center of gravity of the aircraft in a manner effectively the reverse of (4). Hence, the burst co-ordinates in this system are:

$$
\begin{aligned}
X_B &= -X'_B + X_H \\
Y_B &= -Y'_B + Y_H \qquad (21) \\
Z_B &= -Z'_B + Z_H
\end{aligned}
$$

<u>N.B.</u> Equations (11) through (16) are only pertinent to the fixed angle fuze. Other fuzes would have different solution; however, the remainder of the equations (1) through (21) are the same for any fuze.

The effects of blast on the aircraft in question can now be considered.

Before determining blast we must first determine if there are any "variable numerators". This is done by testing the "variable numerator sentinel." If the sentinel is positive or zero, there are no variable numerators, and we determine blast effects. If the sentinel is negative, there are variable numerators, and we find what they are and then determine blast effects.

Variable numerators occur in the equations for the shielding and/or blast ellipsoids.

The ellipsoids which are tested in the blast section define the shape of the aircraft under study. The shielding ellipsoids define the aircraft itself while the blast ellipsoids define a volume such that if the warhead of the missile under evaluation detonates within this volume the aircraft will be killed. If the warhead detonates outside this volume the aircraft will not be killed. This is a zero-one probability.

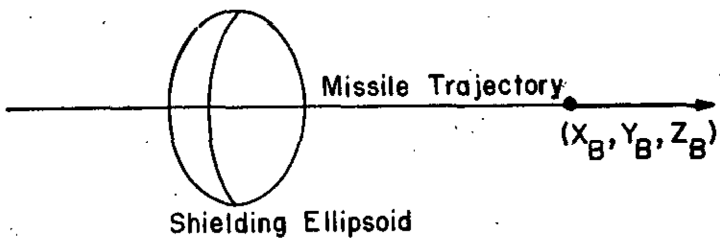
The presence of one or more of the variables, X, Y, or Z, in the numerator of an ellipsoid rotates the ellipsoid so that its axes are not parallel to the co-ordinate axes. It also changes the lengths of the semi-axes from a, b and c.

Having done the above we go on to determine whether there is any external blast. This is done by substituting the burst point (X_B, Y_B, Z_B) in the equations of each blast ellipsoid until

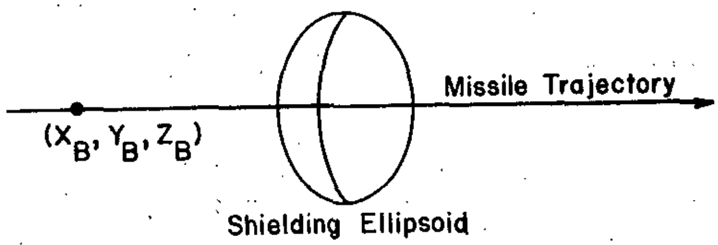
$$\frac{(X_B - C_1)^2}{a^2} + \frac{(Y_B - C_2)^2}{b^2} + \frac{(Z_B - C_3)^2}{c^2} < 1 \qquad (22)$$

for some ellipsoid or all ellipsoids have been tested. If there is external blast, we investigate internal blast. This is done in the same manner except that we use the shielding ellipsoids in equation (22).

If there is no external blast or no internal blast we test for perforation or debris type kills. A perforation type kill is defined as occurring if the missile enters and leaves some part of the target and explodes after exiting, i.e., pictorially,



A debris type kill is defined as a kill resulting if and when the missile trajectory intersects some part of the target and the explosion occurs before entry. Pictorially,



After fully determining the above we go on to the fragmentation section. This section is independent of the fuzing section and the only requirements are that we have a burst point (X_B, Y_B, Z_B) in specified locations and we have the direction cosines given in equations (1), (2), and (3).

NOTE: A full explanation of the Perforation and Debris calculations will be found in Appendix B. The normal random number generator is described in BRL Report 867.

FRAGMENTATION SECTION

Since target travel must be taken into account, after determining the burst point we incorporate a bias dependent upon fragment speed. An iteration center (usually the center of gravity of the target (0,0,0) but not necessarily) is given, and the angle β between the missile trajectory and the path the fragment would have to travel if it were to strike this iteration center (X_R, Y_R, Z_R) is determined from

$$\cos \beta = \frac{(X_R - X_B)\ell'_T + (Y_R - Y_B^*)m'_T + (Z_R - Z_B)n'_T}{(X_R - X_B)^2 + (Y_R - Y_B^*)^2 + (Z_R - Z_B)^2} \; . \tag{23}$$

Since

$$\frac{(X_R - X_B)}{(X_R - X_B)^2 + (Y_R - Y_B)^2 + (Z_R - Z_B)^2}$$

$$\frac{(Y_R - Y_B)}{(X_R - X_B)^2 + (Y_R - Y_B)^2 + (Z_R - Z_B)^2}$$

and

$$\frac{(Z_R - Z_B)}{(X_R - X_B)^2 + (Y_R - Y_B)^2 + (Z_R - Z_B)^2}$$

are the direction cosines of line between (X_R, Y_R, Z_R).

Since we are going to iterate Y_B, we form the following:

$$\begin{aligned} A_2 &= (X_R - X_B)\ell'_T + (Z_R - Z_B)n'_T \\ A_3 &= (X_R - X_B)^2 + (Z_R - Z_B)^2 \end{aligned} \tag{24}$$

The iteration is done only in the Y direction since the target is moving only in that direction. Then let $(Y_B = Y_B^*)$ and form

$$\text{Cos } \beta = \frac{A_2 + (Y_R - Y_B^*)m_T'}{A_3 + (Y_R - Y_B^*)^2} \tag{25}$$

By testing cos β against the spray angles, we determine which spray the fragment would be in if it struck the target at this angle and we choose the corresponding α (ballistic coefficient) and V_0 (initial fragment velocity at the missile warhead).

The time it would take the fragment to traverse this path is given by:

$$t = \frac{e^{+\alpha D_1} - 1}{V_o} \quad , \tag{26}$$

where

$$D_1 = \sqrt{(X_R - X_B)^2 + (Y_R - Y_B^*)^2 + (Z_R - Z_B)^2}$$

The distance traveled by the target in this time is $V_T t$, where V_T is the target velocity which is given. The new Y_B co-ordinate is then

$$Y_B^* = Y_B + tV_T \tag{27}$$

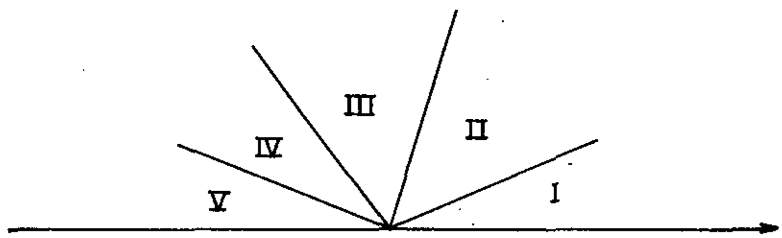
where Y_B is the original Y_B of the burst point computed in the fuzing section.

We perform this iteration three times and now have a new Y co-ordinate of our burst point. This new burst point (X_B, Y_B^*, Z_B) is then used in all subsequent calculations in the fragmentation section.

We are now prepared to treat each of the vulnerable components of the aircraft. We first find the cosine of the angle between the missile path and the path traveled by the fragment to the first vulnerable component from an equation much like (23) above except that now we replace the iteration center with the vulnerable component center (X_T, Y_T, Z_T) and we have

$$\cos\,(V_F, V_M) = \frac{(X_T - Y_B)\ell_T' + (Y_T + Y_B^*)m_T' + (Z_T - Z_B)n_T'}{\sqrt{(X_T - X_B)^2 + (Y_T - Y_B^*)^2 + (Z_T - Z_B)^2}} \tag{28}$$

The denominator of this fraction is designated as D and used in later calculations. Again we determine into which spray this angle will fall by testing it against the cosines of the given spray angles, γ_1, γ_2, γ_3, γ_4. We choose the α and V_o and this time N and m corresponding to the spray into which the angle falls. N is the number of fragments per steradian and m is the square root of the mass of each fragment. At present the code distinguishes five sprays, thusly:



Each of these zones (I, II, III, IV, V) has a set of numbers associated with it, that is, an N, α, V_0, and m. The only restrictions on the γ_i's are that $\gamma_3 \geq 90^\circ$, $\gamma_2 \leq 90^\circ$ and any $\gamma_{i+1} \geq \gamma_i$.

We then check to see if the component is shielded. We do this by determining if one of the shield ellipsoids falls between the two points (X_B, Y_B^*, Z_B) and (X_T, Y_T, Z_T), where the latter is the vulnerable component center and the former is the burst point. The logic of this routing is explained in Appendix B. These are the same as those used in equation (28). If a shield falls between these two points, we say the component is shielded, store a zero in the probability of killing that particular component, and then go on to studying the next component. If, however, no shield falls between these two points the component is unshielded and we determine the probability of killing it in the following manner.

We first compute the striking velocity of the fragment. This is done by computing the remaining velocity of the fragment at the component ($\bar{V}$), it is given by the formula

$$\bar{V} = V_0 e^{-\alpha D} \tag{29}$$

Then the striking velocity is

$$V_s = \bar{V}^2 + V_T^2 + 2\bar{V} V_T \frac{(Y_T - Y_B^*)}{D} . \tag{30}$$

In order to find the vulnerable area of the component we must form w, where

$$w = V_s m^{1/2} \times 10^{-4} \tag{31}$$

We compute a given function for the particular vulnerable component under consideration, viz.,

$$A_v = f_i(w) \tag{32}$$

where A_v is the vulnerable area of the component.

Equation (32) varies for each vulnerable component and each target. The equations describing the A_v's are given for each target. We are now in a position to compute the probability of killing this component. We call this quantity P_k and say that

$$P_k = 1-e^{-\left(\frac{NA_v}{D^2}\right)} . \tag{33}$$

D is defined by equation (28), A_v by equation (32), and N is given. If the quotient $\frac{NA_v}{D^2}$ is greater than 16 we store a one in the probability of kill for this component since the function of e here calculated would be too small to make a significant difference in equation (33).

We then go back and determine the same things from equations (28) through equations (33) for all components until we have found P_k's for all vulnerable components.

COMBINATORIALS

When the blast kills on the overall target structure and fragmentation kills for all components have been determined and recorded, we go to the section of the code which combines them into various combinations of kills, e.g., is there a blast and pilot kill?

We sum these combined probabilities for each round and then go to the output section.

OUTPUT

In this section we determine if we have computed the given number of rounds (B^*), usually 200, and if not we go back to finding a new Azimuth and Elevation and proceed through the entire code once more.

If, however, we have computed kills for all rounds we divide the summed combinatorials by the number of rounds done and print out these average kill probabilities. We then return to the input section, where we read a new set of blast ellipsoids and the other data which follow these up to and including the delay time (D_t), and proceed as before until finished.

This machine simulation has effectively calculated the single shot kill probabilities of various missiles against various aircraft.

Anthony David Stiegler

ANTHONY DAVID STIEGLER

APPENDIX A

LOCATION	CONTENTS	INPUT SCALING	MACHINE SCALING
303	S	10^{-5}	2^{-19}
304	T	10^{-5}	2^{-19}
305	B	10^{-5}	2^{-19}
306	G	10^{-5}	2^{-19}
307	P	10^{-5}	2^{-19}
308	E	10^{-5}	2^{-19}
309	N_B	10^{-5}	2^{-19}
30K	F	10^{-5}	2^{-19}
N00 - N7L	Shield Numerators	10^{-5}	2^{-20}
	Shield Denominator	10^{-5}	2^{-8}
N80 - N11	Target Centers	10^{-5}	2^{-20}
J00 - J7L	Glitter Points	10^{-5}	2^{-20}
J80 - J11	Blast Numerators	10^{-5}	2^{-20}
	Blast Denominators	10^{-5}	2^{-8}
F00 - F04	N_1 - N_5	10^{-5}	2^{-15}
F05 - F09	$V_{o,1}$ - $V_{o,5}$	10^{-5}	2^{-15}
F0K	σ_x	10^{-5}	2^{-11}
F0S	σ_y	10^{-5}	2^{-11}
F0N	σ_F	10^{-5}	2^{-11}
F0J	V_m	10^{-5}	2^{-15}
F0F	V_T	10^{-5}	2^{-15}
F0L	B*	10^{-5}	2^{-10}

APPENDIX A (Continued)

LOCATION	CONTENTS	INPUT SCALING	MACHINE SCALING
F10	$\tan^2\theta$	10^{-5}	2^{-8}
F11 - F13	X_R, Y_R, Z_R	10^{-5}	2^{-20}
F14 - F17	$\gamma_1 - \gamma_4$	10^{-5}	$\gamma_1/360 \times 2^0$
F18 - F1N	$\alpha_1 - \alpha_3$	10^0	2^0
F1J - F21	$m_1^{1/2} - m_3^{1/2}$	10^{-4}	2^0
F22 - F23	Percentages	10^0	2^0
F24	Variable Num. Sent.	Positive - No Variable	Negative - Variable Numerators at 920
F25 - F2J	Homing Points	10^{-5}	2^{-20}
F30	D_t in seconds	10^0	2^0

LOCATION	CONTENTS	DESCRIPTION
4N0	08 008 00 303	C.W. No. 1
4N1	08 000 00 N00	C.W. No. 2
4N2	08 000 00 N80	C.W. No. 3
4N3	08 000 00 J00	C.W. No. 4
4N4	08 000 00 J80	C.W. No. 5
4N5	08 031 00 F00	C.W. No. 6
4N6	03 33J 80 380	BKW. No. 1
4N7	00 69L 01 69J	BKW. No. 2
4N8	03 33N 00 38N	IBKW No. 1
4N9	00 69L 01 6KW	IBKW No. 2
4NK	03 33N 00 360	SKW No. 1
4NS	00 7S4 00 7S5	SKW No. 2
4NN	00 003 00 000	K for iteration
4NJ	03 33N 00 345	PKW No. 1
4NF	00 6K9 00 6K4	PKW No. 2
4NL	00 FOK 00 300	C.W. NRNSR
4J0	08 008 00 390	KWO
4J1	2^{-22}	
4J2	2^{-15}	
4J3	$10^5 \times 2^{-19}$	
4J4	$10^5 \times 2^{-20}$	
4J5	$10^5 \times 2^{-17}$	
4J6	10×2^{-15}	

LOCATION	CONTENTS	DESCRIPTION
4J7	360×10^{-5}	
4J8	12×2^{-19}	
4J9	$5^{13} \times 2^{-39}$	
4JK	45/360	
4JS	90/360	
4JN	180/360	
4JJ	16×2^{-10}	
4JF	Not Used	
4JL	16×2^{-15}	
4F0	00 N00 00 N00	Shield Numerator Address
4F1	00 000 00 564	Return Address Change
4F2	00 J80 00 J80	Blast Address
4F3	00 390 00 390	Address of Σ's
4F4	00 N80 00 N80	Target Center Address
4F5	00 380 00 380	P_o Address
4F6	i_{GP}	Counter for glitter pts.
4F7	00 K00 00 K00	Pilot A_v Address
4F8	00 K40 00 K40	Engine A_v Address
4F9	00 K80 00 K80	Bomb A_v Address
4FK	00 KN0 00 KN0	Fuel Line A_v Address
4FS	C	Counter for iteration

LOCATION	CONTENTS	DESCRIPTION
300	α_2'	Normal Random Number x σ_x
301	α_3'	Normal Random Number x σ_y
302	ϵ	Normal Random Number x σ_F
303	S	Number of Shields x 2^{-19}
304	T	Number of Targets x 2^{-19}
305	B	Number of Blasts x 2^{-19}
306	G	Number of Glitter Pts. x 2^{-19}
307	P	Number of Pilots x 2^{-19}
308	E	Number of Engines x 2^{-19}
309	N_B	Number of Bombs x 2^{-19}
30K	F	Number of Fuel Lines x 2^{-19}
30	3B	3 times the number of Blasts x 2^{-19}
30N	ρ_o	Uniform Random Number
30J	N_1^p	B* times first Percentage x 2^{-10}
30F	N_2^p	N_1^p + B* times second Percentage x 2^{-10}
30L	b	Present round x 2^{-10}
310	α	Present drag coefficient x 2^0
311	V_o	Present fragment velocity x 2^{-15}
312	N	Present number of fragments x 2^{-15}
313	m	Present fragment weight x 10^{-4} x 2^0

LOCATION	CONTENTS	DESCRIPTION
314	A	Azimuth Angle divided by 360×2^0
315	E	Elevation Angle divided by 360×2^0
316	λ_1	
317	λ_2	Direction cosines of α_1 axis $\times 2^{-1}$
318	λ_3	
319	ρ_1	
31K	ρ_2	Direction cosines of α_2 axis $\times 2^{-1}$
31	ρ_3	
31N	γ_1	
31J	γ_2	Direction cosines of α_3 axis $\times 2^{-1}$
31F	γ_3	
31L	ℓ_M	
320	m_M	Direction cosines of Target with respect to missile $\times 2^{-1}$
321	n_M	
322	ℓ''_M	Direction cosines of Relative Velocity
323	m''_M	Vector with respect to missile $\times 2^{-1}$
324	n''_M	

LOCATION	CONTENTS	DESCRIPTION
325	ℓ'_t	Direction cosines of missile with respect to target x 2^{-1}.
326	m'_t	
327	n'_t	
328	X_{GP}	Coordinates of present
329	Y_{GP}	Coordinates of present glitter point x 2^{-20} (with respect to target)
32K	Z_{GP}	
32S	$\Delta\alpha_{1GP}$	Coordinates of present glitter point x 2^{-20} (with respect to missile)
32N	$\Delta\alpha_{2GP}$	
32J	$\Delta\alpha_{3GP}$	
32F	Y^*_B	Iterate burst point for fragmentation
32L	α_{1f}	α_1 - coordinate of fuze pt., largest so far
330	α_{1B}	
331	α_{2B}	Coordinates of Burst Point with respect to missile x 2^{-20}
332	α_{3B}	
333	X_B	Coordinates of Burst Point with respect to target x 2^{-20}
334	Y_B	
335	Z_B	
336	V_R	Relative Velocity Vector x 2^{-15}

LOCATION	CONTENTS	DESCRIPTION
337	A	$(\alpha_2' + \Delta\alpha_{2GP} - m''/\ell''\ \Delta\alpha_{1GP}) \times 2^{-20}$
338	B	$(\alpha_3' + \Delta\alpha_{3GP} - n''/\ell''\ \Delta\alpha_{1GP}) \times 2^{-20}$
339	b	$\dfrac{\ell''(m''A + n''B)}{m''^2 + n''^2 - \ell''^2 \tan^2\theta} \times 2^{-10}$
33K	c	$\dfrac{\ell''^2(A^2 + B^2)}{m''^2 + n''^2 - \ell''^2 \tan^2\theta} \times 2^{-10}$
33S	A_2	$((X_R - X_B)\ell_t' + (Z_R - Z_B)n_t') \times 2^{-15}$
33N	A_3	$((X_R - X_B)^2 + (Z_R - Z_B)^2) \times 2^{-15}$
33J	A_1	$(Y_R - Y_B^*)m_t' + A_2 \times 2^{-15}$
33F	D_1	$\sqrt{(Y_R - Y_B^*)^2 + A_3} \times 2^{-15}$
33L	M	Number of targets done so far $\times 2^{-19}$
340	W	$(V_s m \times 10^{-4}) \times 2^{-10}$
341	A_v	Present $A_v \times 2^{-15}$
342	C_1	$(\ell_t'(x_T - x_B) + m_t'(y_T - y_B) + n_t'(z_T - z_B)) \times 2^{-11}$
343	D	$((x_T - x_B)^2 + (x_T - y_B)^2 + (z_T - z_B)^2) \times 2^{-10}$

LOCATION	CONTENTS	DESCRIPTION
344	$\cos V_m V_T$	$(C_1/D) \times 2^{-1}$
345	ℓ''_T	Direction cosine of Relative Velocity
346	m''_T	Vector with respect to the target $\times 2^{-1}$
347	n''_T	
350	TEMPORARY	
355	STORAGE	
360	X_T	
361	Y_T	Present target coordinates $\times 2^{-20}$
362	Z_T	
371	$(\cos \gamma_1) \times 2^{-1}$	
372	$(\cos \gamma_2) \times 2^{-1}$	
373	$(\cos \gamma_3) \times 2^{-1}$	
374	$(\cos \gamma_4) \times 2^{-1}$	
390 - 39S	$\sum_0 - \sum_{11}$	
380 - 38S	$P_{K,0} - P_{K,11}$	

APPENDIX B

PERFORATION OR DEBRIS:

The problem is to determine whether the trajectory of the missile intersects one of the target components (given by the shielding ellipsoids) and whether burst occurs before entry or after exit.

The problem mathematically is to find the solution of a line intersecting an ellipsoid. The equations are

The line:

$$(a)\quad x = x_B + t\,\ell''_T,\; y = y_B + t\,m''_T,\; z = z_B + t\,n''_T\,,$$

where

$$0 \quad t \quad 1 \tag{B.1}$$

The ellipsoid:

$$(b)\quad \left(\frac{x - C_1}{d_1}\right)^2 + \left(\frac{y - C_2}{d_2}\right)^2 + \left(\frac{z - C_3}{d_3}\right)^2 = 1,$$

where ℓ''_T, m''_T, and n''_T are the direction cosines of the relative velocity vector with respect to the target, and the ellipsoids are the shielding ellipsoids which are given.

Substituting (a) (B.1) into (b) (B.1) gives

$$\left[\frac{x_B + t\ell''_T - C_1}{d_1}\right]^2 + \left[\frac{y_B + tm''_T - C_2}{d_2}\right]^2 + \left[\frac{z_B + tn''_T - C_3}{d_3}\right]^2 = 1$$

or

$$\left[\frac{X_B - C_1}{d_1} + \frac{t\,\ell''_T}{d_1}\right]^2 + \left[\frac{Y_B - C_2}{d_2} + \frac{t\,m''_T}{d_2}\right]^2 \tag{B.2}$$

$$+ \left[\frac{Z_B - C_3}{d_3} + \frac{t\,n''_T}{d_3}\right]^2 - 1 = 0$$

Squaring the terms in equation (B.2) and combining terms gives

$$t^2\left[\left(\frac{\ell''_T}{d_1}\right)^2 + \left(\frac{m''_T}{d_2}\right)^2 + \left(\frac{n''_T}{d_2}\right)^2\right] + 2t\left[\left(\frac{X_B - C_1}{d_1}\right)\left(\frac{\ell''_T}{d_1}\right)\right.$$

$$\left. + \left(\frac{Y_B - C_2}{d_2}\right)\left(\frac{m''_T}{d_2}\right) + \left(\frac{Z_B - C_3}{d_3}\right)\left(\frac{n''_T}{d_3}\right)\right] + \qquad \text{(B.3)}$$

$$+\left(\frac{X_B - C_1}{d_1}\right)^2 + \left(\frac{Y_B - C_2}{d_2}\right)^2 + \left(\frac{Z_B - C_2}{d_3}\right)^2 - 1 = 0.$$

Letting

$$\vec{A} = (a_1, a_2, a_3) \qquad \text{(B.4)}$$

$$\vec{G} = (g_1, g_2, g_3)$$

where

(a) $$a_1 = \frac{\ell''_T}{d_1}, \quad a_2 = \frac{m''_T}{d_2}, \quad a_3 = \frac{n''_T}{d_3} \qquad \text{(B.5)}$$

(b) $$g_1 = \frac{(X_B - C_1)}{d_1}, \quad g_2 = \frac{(Y_B - C_2)}{d_2}, \quad g_3 = \frac{(Z_B - C_3)}{d_3}$$

equation (B.3) becomes

$$\left[\vec{A} \cdot \vec{A}\right]t^2 + 2\left[\vec{A} \cdot \vec{G}\right]t + \left[\vec{G} \cdot \vec{G}\right] - 1 = 0 \qquad \text{(B.6)}$$

If equation (B.6) has two real and distinct roots there is either perforation or debris. Since perforation is defined as occurring when the missile has entered and left some part of the target and exploded

after exit, both roots must be negative, or the following criteria must hold:

$$(a) \quad (\vec{A} \cdot \vec{A})(\vec{G} \cdot \vec{G} - 1) - (\vec{A} \cdot \vec{G})^2 < 0$$

$$(b) \quad \vec{G} \cdot \vec{G} - 1 \geq 0 \qquad (B.7)$$

Condition (a) (B.7) means that there are two real, unequal roots. Condition (b) (B.7) means that the roots have the same sign since A . A must be positive. Condition (c) (B.7) means that at least one root is negative.

Debris is defined as the condition arising when the missile trajectory intersects the target and the missile explodes before entry. Therefore, both roots of equation (B.6) must be real and positive. Conditions (a) (B.7) and (b) (B.7) above must again hold. However, in place of condition (c) (B.7) the following must hold

$$(d) \quad \vec{A} \cdot \vec{G} < 0 \qquad (B.7)$$

This means that at least one root is positive, since A . A is always positive.

If condition (a) (B.7) does not hold there is, obviously, neither type of kill.

This analysis is for all ellipsoids until conditions (a) (B.7) and (b) (B.7) and (c) (B.7) or (d) (B.7) are met or all ellipsoids have been tested.

SHIELDING:

Here the problem is, as above, to solve for the intersection of a line and an ellipsoid. However, in this case the equation of the line is (B.8)

$$X = X_B + t(X_T - X_B), \quad y = y_B + t(Y_T - Y_B), \quad Z = Z_B + t(Z_T - Z_B)$$

where $0 \leq t \leq 1$.

Substituting these values in equation (b) (B.1), gives an equation similiar to equation (B.6). The equation is

$$\left[\vec{B} \cdot \vec{B}\right] t^2 + 2\left[\vec{B} \cdot \vec{G}\right] t + \left[\vec{G} \cdot \vec{G}\right] - 1 = 0 \qquad \text{(B.9)}$$

and

$$\vec{B} = (b_1, b_2, b_3) \qquad \text{(B.10)}$$

and

$$b_1 = \frac{(X_T - X_B)}{d_1} \quad , \quad b_2 = \frac{(Y_T - Y_B)}{d_2} \quad , \quad b_3 = \frac{(Z_T - Z_B)}{d_3} \qquad \text{(B.11)}$$

The path of the fragment must intersect the ellipsoid; i.e., the quadratic (B.9) has real roots, also the ellipsoid must fall between the two points (i.e., neither point can be within the ellipsoid in question). Therefore, the two roots t_1 and t_2 of equation (B.9) must meet the following criteria:

$$0 < t_1 \quad t_2 < 1 \qquad \text{(B.12)}$$

Since (B.9) is a function of t, and if it is designated by f(t), then the ellipsoid shields the component if, and only if, it satisfies the following requirements:

(a) $(\vec{B} \cdot \vec{B})(\vec{G} \cdot \vec{G} - 1) - (\vec{B} \cdot \vec{G})^2 < 0$

(b) $f(0) \geq 0$

(c) $f(1) \geq 0$ (B.13)

(d) $f'(0) < 0$

(e) $f'(1) \geq 0$

where $f'(t)$ is the derivative of the function with respect to t.

If condition (a) (B.13) holds both the roots are real. If conditions (b) (B.13) and (c) (B.13) hold then neither the point (X_B, Y_B, Z_B) nor the point (X_T, Y_T, Z_T), respectively, are inside the ellipsoid. If conditions (d) (B.13) and (e) (B.13) hold there is either a maximum or minimum between 0 and 1. Since condition (a) (B.13) is tested first, this means that there is a root between 0 and 1. Thus conditions (B.13) are synonymous with conditions (B.12).

If none of the ellipsoids meet the requirements (B.13) the component is not shielded. However, if at least one ellipsoid meets these requirements, then the component is shielded.

0 1 2 3 4 5 6 7 8 9 K S N J F L 0 1 2 3 4 5 6 7 8 9 K S N J F L

00		01
02		03
04	040	05
06	I B M I	07
08		09
0K	0K9	0S
0N		0J
0F	I B M O	0L
10		11
12	1 39	13
14	$\sqrt{}$	15
16		17
18	? 18L	19
1K	Shield	1S
1N	1N9	1J
1F	Blast	1L
20	205	21
22	Per f	23
24	24F	25
26	C^x	27
28	283 N R N S. R.	29
2K		2S
2N		2J
2F		2L
30		31
32	COMPUTED NUMBERS AND	33
34		35
36	NECESSARY ASSIGNED TEMPORARY	37
38		39
3K	STORAGE	3S
3N	350 - BEGINNING OF UNASSIGNED	3J
3F	TEMPORARY STORAGE	3L

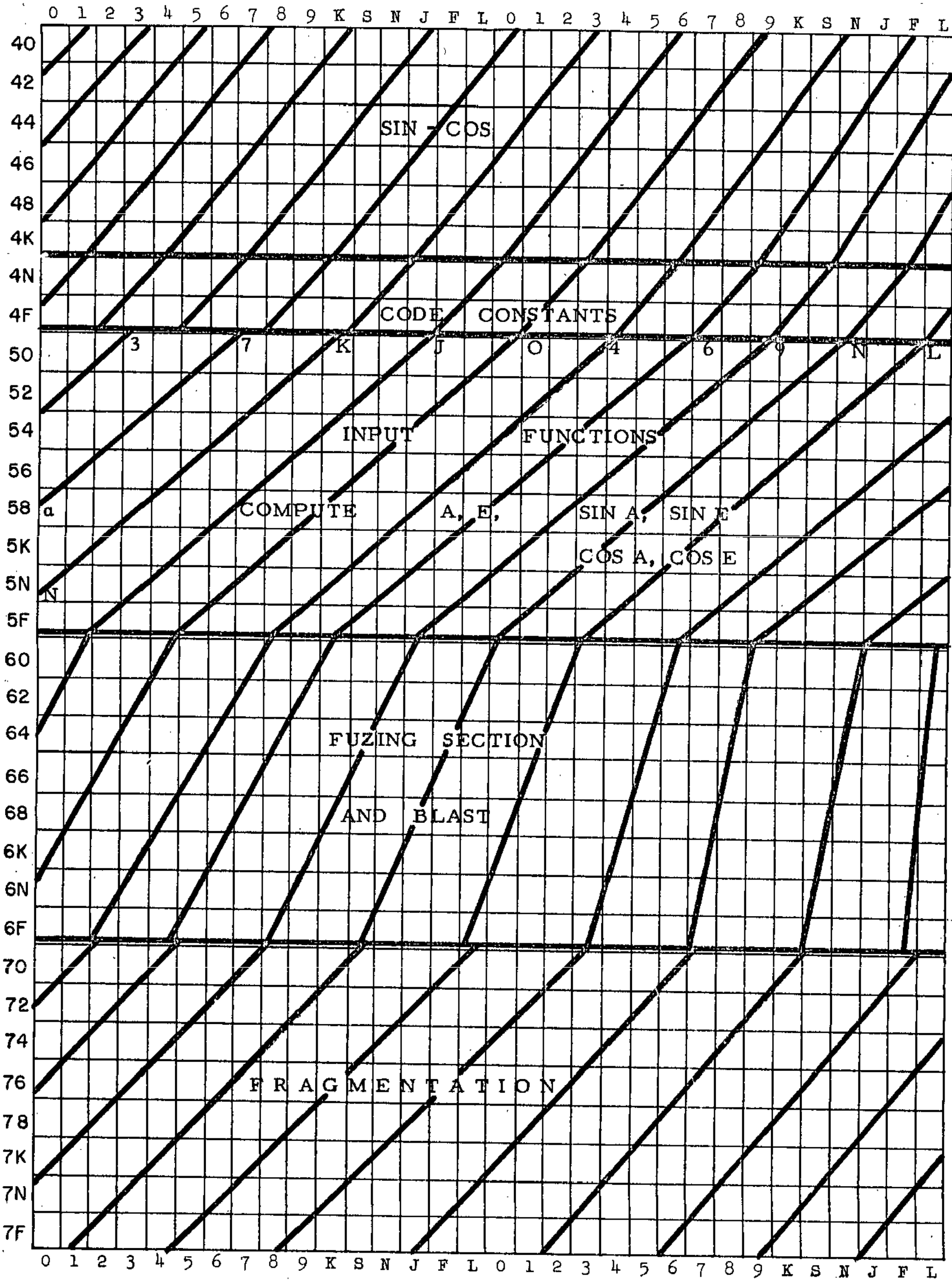
0 1 2 3 4 5 6 7 8 9 K S N J F L 0 1 2 3 4 5 6 7 8 9 K S N J F L

N00-LLL

	0	1	2	3	4	5	6	7	8	9	K	S	N	J	F	L	0	1	2	3	4	5	6	7	8	9	K	S	N	J	F	L	
N0																																	N1
N2													SHIELDS																				N3
N4																																	N5
N6																																	N7
N8																																	N9
NK													TARGETS																				NS
NN																																	NJ
NF																																	NL
J0																																	J1
J2													GLITTER POINTS																				J3
J4																																	J5
J6																																	J7
J8																																	J9
JK													BLASTS																				JS
JN																																	JJ
JF																																	JL
F0																																	F1
F2																																	F3
F4																																	F5
F6													MISCELLANY																				F7
F8																																	F9
FK																																	FS
FN																																	FJ
FF																																	FL
L0																																	L1
L2																																	L3
L4																																	L5
L6																																	L7
L8																																	L9
LK																																	LS
LN																																	LJ
LF																																	LL
	0	1	2	3	4	5	6	7	8	9	K	S	N	J	F	L	0	1	2	3	4	5	6	7	8	9	K	S	N	J	F	L	

Column headings (top and bottom of grid): 0 1 2 3 4 5 6 7 8 9 K S N J F L 0 1 2 3 4 5 6 7 8 9 K S N J F L

00		01
02		03
04		05
06	COMBINATORIALS	07
08		09
0K		0S
0N		0J
0F		0L
90	OUTPUT FUNCTIONS	91
92		93
94	VARIABLE NUMERATOR	95
96		97
98	CALCULATION	99
9K		9S
9N		9J
9F		9L
K0		K1
K2	Av CALCULATIONS	K3
K4		K5
K6	PILOT AV at K00	K7
K8	ENGINE AV at K40	K9
KK	BOMB AV at K80	KS
KN	FUEL LINE AV at KN0	KJ
KF	OTHERS WILL START AT $00	KL
$0		$1
$2		$3
$4		$5
$6		$7
$8		$9
$K		$S
$N		$J
$F		$L



0 1 2 3 4 5 6 7 8 9 K S N J F L 0 1 2 3 4 5 6 7 8 9 K S N J F L
40
42
44
46
48
4K
4N
4F
50
52
54
56
58
5K
5N
5F
60
62
64
66
68
6K
6N
6F
70
72
74
76
78
7K
7N
7F
41
43
45
47
49
4S
4J
4L
51
53
55
57
59
5S
5J
5L
61
63
65
67
69
6S
6J
6L
71
73
75
77
79
7S
7J
7L
SIN - COS
CODE CONSTANTS
3
7
K
J
O
4
6
9
N
L
INPUT FUNCTIONS
a
COMPUTE A, E, SIN A, SIN E
COS A, COS E
N
FUZING SECTION
AND BLAST
FRAGMENTATION

80 003
20 4N0

Date.

ORDVAC Problem No.
Sheet

Seq.	CODE		ADDRESS	ORDER	R_1	R_2	Description
	08	008	4N0	CW 1			
	00	303					
	08	000	1	CW 2			
	00	N00					
	08	000	2	CW 3			
	00	N80					
	08	000	3	CW 4			
	00	J00					
	08	000	4	CW 5			
	00	J80					
	08	031	5	CW 6			
	00	F00					
	03	33J	6	BKW 1			
	80	380					
	00	6$1	7	BKW 2			
	01	6KL					
	03	33N	8	IBKW 1			
	00	38N					
	00	6$1	9	IBKW 2			
	01	700					
	03	33N	K	SKW 1			
	00	360					
	00	7$3	$	SKW 2			
	00	7$4					
	00	003	N	K for			
	00	000		Iteration			
	03	33N	J	PKW1			
	00	345					
	00	6$8	F	PKW 2			
	00	6$3					
	00	FOK	L	C.W. NR	N		
	00	300					

ORDVAC Problem No. ______

Date ______ Sheet ______

Seq.	CODE		ADDRESS	ORDER	R_1	R_2	Description
	08	008	4J0	KWO			
	00	390					
	00	000	1	2^{-22}			
	20	000					
	00	010	2	2^{-15}			
	00	000					
80 003	K19	073	3	$10^5 \times 2^{-19}$			
00 4J3	486	328					
	K09	536	4	$10^5 \times 2^{-20}$			
	743	164					
	K76	293	5	$10^5 \times 2^{-17}$			
	945	313					
	K00	030	6	10×2^{-15}			
	517	578					
	K00	360	7	360×10^{-5}			
	000	000					
80 003	00	009	8	9×2^{-19}			
20 4J8	00	000					
	00	48N	9	513×2^{-39}			
	27	395					
	10	000	K	$45/360 = \frac{1}{8}$			
	00	000					
	20	000	$	$90/360 = \frac{1}{4}$			
	00	000					
	40	000	N	$180/360 = \frac{1}{2}$			
	00	000					
	021	000	J	16×2^{-10}			
	00	000					
	00	F25	F	Home Pt.			
	00	F25		Address			
	00	100	L	16×2^{-15}			
	00	000					

ORDVAC Problem No.

Date

Sheet

Seq.	CODE	ADDRESS	ORDER	R_1	R_2	Description
	00 N00	4F0	SN ADD			
	00 N00					
	00 000	1	Return			
	00 564		Add Change			
	00 J80	2	Blast Add			
	00 J80					
	00 390	3	Add Σ			
	00 390					
	00 N80	4	TC Add			
	00 N80					
	00 380	5	P_o Add			
	00 380					
	00 000	6	i or p			
	00 000		counter			
	00 K00	7	pilot or			
	00 K00		Add			
	00 K40	8	Eng A_v			
	00 K40		Add.			
	00 K80	9	Bomb A_v			
	00 K80		Add.			
	00 KN0	K	Fuel Line			
	00 KN0		A_v Add			
	00 000	$	Counter			
	00 000		For Iteration			
	00 003	N	Address			
	00 003		Increment			
	00 J00	J	Glitter Pt.			
	00 J00		Address			
		F				
		L				

ORDBG Form 1351-(R)
Rev 26 Mar 57

Army--APG, Md--O

80 003
20 500

ORDVAC Problem No.______

Date ______

Sheet ______

Seq.	CODE	ADDRESS	ORDER	R_1	R_2	Description
	30 350	500	oMTSO			
	30 351		oMTS1			
	30 352	501	oM TS2			
	30 353		oM TS3			
	K4 4N0	502	+ CW 1	08 008 01	AAA	
	$4 503		R R.A			
	$N 040	503	U*IBMI			
	00 504		— R.A.			
	$4 303	504	R $		$\$ \times 10^{-5}$	
	68 4J3		$X10^5 x\ 2^{-19}$	$\$ \times 2^{-19}$		
	N4 4J1	5	(+) 2^{-22}			
	90 350		ETSO			
	$4 304	6	RT		$T \times 10^{-5}$	
	68 4J3		$X10^5 x\ 2^{-19}$	$B \times 2^{-19}$		
	N4 4J1	7	(+) 2^{-22}			
	90 351		ETSI			
	$4 305	8	RB		$B \times 10^{-5}$	
	68 4J3		$X10^5 x\ 2^{-19}$	$G_1 \times 2^{-19}$		
	N4 4J1	9	(+) 2^{-22}			
	90 352		ETS2			
	$4 306	K	R G_1		$G_1 \times 10^{-5}$	
	68 4J3		$X10^5 x\ 2^{-19}$	$G_1 \times 2^{-19}$		
	N4 4J1	$	(+) 2^{-22}			
	90 353		ETS3			
	K4 350	N	+TSO	$		
	18 001		← 1	2$		
	N4 350	J	(+) TSO	3$		
	18 001		← 1	6$		
	90 4N1	F	E CW2			
	K4 351		+ TS1	T		
	18 001	L	← 1	2T		
	N4 351		(+) TS1	3T		

ORDVAC Problem No. ________

Date ________ Sheet ________

Seq.	CODE	ADDRESS	ORDER	R_1	R_2	Description
	90 4N2	510	ECW3			
	K4 353		+T$3	G_1		
	18 001	1	← 1	$2G_1$		
	N4 353		(+) T$3	$3G_1$		
	90 4N3	2	ECW4			
	K4 352		+TS2	B		
	18 001	3	← 1	2B		
	N4 352		(+) TS2	3B		
	18 001	4	← 1	6B		
	90 4N4		ECW5			
	K4 4N1	5	+CW2			
	$4 516		R RA_2			
	$N 040	6	U*IBMI			Read Shields
	00 517		-R A_3			
	K4 4N2	7	+CW3			
	$4 518		R RA_3			
	$N 040	8	U*IBMI			Read Target
	00 519		- RA_3			Centers
	K4 4N3	9	+CW4			
	$4 51K		R RA_4			
	$N 040	K	U*IBMI			Read Glitter
	00 51$		-RA_4			Points
	$4 307	$	RP		$P \times 10^{-5}$	
	68 4J3		$X2^{-19} x 10^5$	$P \times 2^{-19}$		
	N4 4J1	N	(+) 2^{-22}			
	90 354		ETS4			
	K4 354	J	+TS4			
	10 307		MP			
	$4 308	F	RE		$E \times 10^{-5}$	
	68 4J3		$X2^{-19} x 10^5$	$E \times 2^{-19}$		
	N4 4J1	L	(+) 2^{-22}			
	90 354		ETS4			

ORDVAC Problem No. ____

Date ____ Sheet ____

Seq.	CODE	ADDRESS	ORDER	R_1	R_2	Description
	K4 354	520	+TS4			
	10 308		ME			
	$4 309	1	R N_B		$N_B \times 10^{-5}$	
	68 4J3		$X2^{-19} \times 10^5$	$N_B \times 2^{-19}$		
	N4 4J1	2	(+) 2^{-22}			
	90 354		ETS4			
	K4 354	3	+TS4			
	10 309		MN_B			
	$4 30K	4	RF		$F \times 10^{-5}$	
	68 4J3		$X10^5 x2^{-19}$	$F \times 2^{-19}$		
	N4 4J1	5	(+) 2^{-22}			
	90 354		ETS4			
	K4 354	6	+TS4			
	10 30K		MF			
	K4 350	7	+TSO			
	10 303		M$			
	K4 351	8	+TS1			
	10 304		MT			
	K4 352	9	+TS3			
	10 306		MG			
	K4 352	K	+TS2			
	10 305		MB			
	K4 4N4	$	+CW5	Start	new Input	here.
	$4 52N		R RA_5			
	$N 040	N	U*IBMI			Read Blasts.
	00 52J		-RA_5			
	K4 4N5	J	+CW6			
	$4 52F		R RA_6			
	SN 040	F	U*IBMI		Read:	N's, a's, V's, etc.
	00 52L		-RA_6	(This Address is changed to 564).		
	K4 303	L	+$	$		
	18 001		← 1	2$		

ORDVAC Problem No.

Date   Sheet

Seq.	CODE	ADDRESS	ORDER	R_1	R_2	Description
	N4 303	530	(+) $	3$		
	10 350		MTSO			
	K4 304	1	+T	T		
	18 001		← 1	2T		
	N4 304	2	(+) T	3T		
	10 351		MTS1			
	K4 305	3	+B	B		
	18 001		← 1	2B		
	N4 305	4	(+) B	3B		
	10 352		MTS2			
	K4 306	5	$+G_1$	G_1		
	18 001		← 1	$2G_1$		
	N4 306	6	$(+) G_1$	$3G_1$		
	10 353		MTS3			
	K4 305	7	+B	$B \times 2^{-19}$		
	18 00N		← 12	$B \times 2^{-7}$		
	N4 4N7	8	(+) BKW2			Initialize External
	10 4N7		MBKW2			Blast Key Word No. 2
	K4 303	9	+$	$\$ \times 2^{-19}$		
	18 00N		← 12	$\$ \times 2^{-7}$		
	N4 4N9	K	(+)IBKW2			Initialize Internal
	10 4N9		MIBKW2			Blast Key Word No. 2
	K4 303	$	+8	$\$ \times 2^{-19}$		
	08 008		→ 8	$\$ \times 2^{-27}$		
	10 354	N	MTS4			
	N4 4N$		(+) SKW2			
	10 4N$	J	MSKW2			
	K4 354		+TS4			
	N4 4NF	F	(+)PKW2			Initialize Perforation
	10 4NF		MPKW2			Key Word No. 2
	30 354	L	oMTS4	O→i		
	$4 N00		R SN1		$SN1 \times 10^{-5}$	Scale Shield Numerators

ORDBG Form 1351-(R)
Rev 26 Mar 57

Army--APG, Md--O

ORDVAC Problem No. ________

Date ________ Sheet ________

Seq.	CODE	ADDRESS	ORDER	R_1	R_2	Description
	68 4J4	540	$X10^5x2^{-20}$			Scale Shield
	10 N00		M SN1	$SN1x2^{-20}$		Numerators
	28 012	1	+→ 18			2^{-20}
	N4 354		(+) TS4	i+1→i		
	10 354	2	MTS4			
	04 350		(-) TSO	i - 3S		
	20 546	3	C546			
	K4 53L		+53L			
	N4 00J	4	$(+)\ 2^{-39}$			
	50 53L		E' 53L			
	50 540	5	E' 540			
	14 53L		U' 53L			
	K4 4F0	6	+SN Add	OOSN1 00000		
	N4 350		+TSO	OOSD1 00000		
	90 54$	7	E 54$			
	08 014		→20	o—o SD1		
	50 549	8	E' 549			
	10 354		MTS4			
	30 354	9	OMTS4	o →i		
	$4 000		R SD1		$SD1 \times 10^{-5}$	Scale Shield
	68 4J5	K	$X2^{-17}x10^5$	$SD1x2^{-17}$		Numerators
	18 009		←9	$SD1x2^{-8}$		2^{-8}
	10 000	$	M (SD1)			
	28 012		+→ 18			
	N4 354	N	(+) TS4			
	10 354		MTS4	i+1→i		
	04 350	J	-TSO	i-3$		
	20 551		C 551			
	K4 549	F	+549			
	N4 00J		$(+)\ 2^{-39}$			
	50 549	L	E' 549			
	18 014		← 20			

ORDBG Form 1351-(R)
Rev 26 Mar 57

Army--APG, Md--O

ORDVAC Problem No. ______

Date ______ Sheet ______

Seq.	CODE	ADDRESS	ORDER	R_1	R_2	Description
	90 54$	550	E 54$			
	14 549		U' 549			
	30 354	551	oMTS4	o→i		Scale Target
	$4 N80		RTC1		TCLx10^{-5}	Centers 2^{-20}
	68 454	552	X10^5x2^{-20}	TC1x2^{-20}		
	10 N80		MTC1			
	28 012	553	+→ 18			
	N4 354		(+) TS4			
	10 354	554	MTS4	i + 1→i		
	04 351		(-) TS1	i - 3T		
	20 558	555	C558			
	K4 551		+551			
	N4 00J	556	(+) 2^{-39}			
	50 551		E' 551			
	50 552	557	E' 552			
	14 551		U' 551			
	30 354	8	oMTS4	o→i		Scale Glitter
	$4 J00		RGP1		GP1x10^{-5}	Points 2^{-20}
	68 4J4	9	X2^{-20}x10^5	GP1x2^{-20}		
	10 J00		MGP1			
	28 012	K	+→ 18			
	N4 354		(+) TS4			
	10 354	$	M+S4	i + 1→i		
	04 353		(-) TS3	i - 3G_1		
	20 55L	N	C55L			
	K4 558		+558			
	N4 00J	J	(+) 2^{-39}			
	50 558		E' 358			
	50 559	F	E' 559			
	14 558		U' 558			
	K4 4F1	L	+ Return	Add ch 0 0 564		
	50 52F		E' 52F			

ORDBG Form 1351-(R)
Rev 26 Mar 57

Army--APG, Md--O

ORDVAC Problem No. ____________

Date ____________ Sheet ____________

Seq.	CODE		ADDRESS	ORDER	R_1	R_2	Description
	K4	352	560	+TS2			
	10	30$		M3B			
	N4	4F2	1	(+) Blast Add			
	90	4F2		E' Blast Whd.	00BD1 00BN1		
	90	56J	2	E 56J			
	08	014		$\rightarrow$ 20			
	50	56$	3	E' 56$			
	10	354		MTS4			
	30	354	4	oMTS4	o $\rightarrow$ i		
	$4	J80		R BN1		BN1x10^{-5}	Scale Blast
	68	4J4	5	X10^5x2^{-20}	BN1x2^{-20}		Numerators 2^{-20}
	10	J80		MBN1			
	28	012	6	+$\rightarrow$ 18			
	N4	354		(+) TS4			
	10	354	7	MTS4	i + 1 $\rightarrow$ i		
	04	30$		(-) 3B	i - 3B		
	20	56$	8	C56$			
	K4	564		+564			
	N4	00J	9	(+) 2^{-39}			
	50	564		E' 564			
	50	565	K	E' 565			
	14	564		U' 564			
	30	354	$	oM+S4	o $\rightarrow$ i		Scale Blast
	$4	000		R (BD1)		BD1x10^{-5}	Denominators 2^{-8}
	68	4J5	N	X2^{-17}x10^5	BD1x2^{-17}		
	18	009		$\leftarrow$ 9	BB1x2^{-8}		
	10	000	J	M (BD1)			
	28	012		+$\rightarrow$ 18			
	N4	354	F	(+) TS4			
	10	354		MTS4	i + 1 $\rightarrow$ i		
	04	30$	L	(-) 3B	i - 3B		
	20	573		C573			

ORDVAC Problem No.

Date

Sheet

Seq.	CODE	ADDRESS	ORDER	R_1	R_2	Description
	K4 56$	570	+ 56$			
	N4 00J		(+) 2^{-39}			
	50 56$	1	E' 56$			
	18 014		← 20			
	90 56J	2	F 56J			
	14 56$		U' 56$			
	K4 4F2	3	+Blast Add	00BD1 00BW1		Initialize Blast
	50 564		E' 564			Denominator and Numerator Scaling
	50 565	4	E' 565			
	90 56J		E 56J			
	08 014	5	→ 20			
	50 56$		E' 56$			
	$4 F00	6	R N_1		$N_1 \times 10^{-5}$	
	68 4J5		$X2^{-17}x10^5$	$N_1 \times 2^{-17}$		
	18 002	7	← 2	$N_1 \times 2^{-15}$		
	10 F00		MN_1			
	$4 F01	8	RN_2		$N_2 \times 10^{-5}$	
	68 4J5		$X2^{-17}x10^5$	$N_2 \times 2^{-17}$		
	18 002	9	← 2	$N_2 \times 2^{-15}$		
	10 F01		M N_2			
	$4 F02	K	R N_3		$N_3 \times 10^{-5}$	
	68 4J5		$X2^{-h}x10^5$	$N_3 \times 2^{-17}$		
	18 002	$	← 2	$N_3 \times 2^{-15}$		
	10 F02		MN_3			
	$4 F03	N	R N_4		$N_4 \times 10^{-5}$	
	68 4J5		$X2^{-17}x10^5$	$N_4 \times 2^{-17}$		
	18 002	J	← 2	$N_4 \times 2^{-15}$		
	10 F03		M N_4			
	$4 F04	F	R N_5		$N_5 \times 10^{-5}$	
	68 4J5		$X2^{-17}x10^5$	$N_5 \times 2^{-17}$		
	18 002	L	← 2	$N_3 \times 2^{-15}$		
	10 F04		M N_5			

ORDBG Form 1351-(R)
Rev 26 Mar 57

Army--APG, Md--O

ORDVAC Problem No.

Date

Sheet

Seq.	CODE		ADDRESS	ORDER	R1	R2	Description
	$4	F05	580	R V_1		$V_1 \times 10^{-5}$	
	68	4J5		$X2^{-17}x10^5$	$V_1 x2^{-17}$		
	18	002	1	← 2	$V_1\ x2^{-15}$		
	10	F05		M V_1			
	$4	F06	2	R V_2			
	68	4J5		$X2^{-17}x10^5$			
	18	002	3	← 2			
	10	F06		M V_2	$V_2 x2^{-15}$		
	$4	F07	4	R V_3			
	68	4J5		$X2^{-17}x10^5$			
	18	002	5	← 2			
	10	F07		M V_3	$V_3 \times 2^{-15}$		
	$4	F08	6	R V_4			
	68	4J5		$X2^{-17}x10^5$			
	18	002	7	← 2			
	10	F08		M V_4	$V_4\ x2^{-15}$		
	$4	F09	8	R V_5			
	68	4J5		$X2^{-17}x10^5$			
	18	002	9	← 2	$V_5\ x2^{-15}$		
	10	F09		M V_5			
	$4	F0K	K	R σx		σx X 10^{-5}	
	68	4J5		$X2^{-17}x10^5$	σx X 2^{-17}		
	18	006	$	← 6	σx X 2^{-11}		
	10	F0K		M σx			
	$4	F0$	N	R σy		σy X 10^{-5}	
	68	4J5		$X2^{-17}x10^5$	σy X 2^{-17}		
	18	006	J	← 6	σy X 2^{-11}		
	10	F0$		M σy			
	$4	F0N	F	R σf		σf X 10^{-5}	
	68	4J5		$X2^{-17}x10^5$	σf X 2^{-17}		
	18	006		← 6	σf X 2^{-11}		
	10	F0N	L	M σf			

ORDBG Form 1351-(R)
Rev 26 Mar 57

Army--APG, Md--O

ORDVAC Problem No. ______

Date ______ Sheet ______

Seq.	CODE	ADDRESS	ORDER	R_1	R_2	Description
	$4 F0J	590	R V_M		$V_M x10^{-5}$	
	68 4J5		$X2^{-17}x10^5$	$V_M x2^{-17}$		
	18 002	1	← 2	$V_M x2^{-15}$		
	10 F0J		M V_M			
	$4 F0F	2	R V_T		V_T $x10^{-5}$	
	68 4J5		$X2^{-17}x10^5$	V_T $x2^{-17}$		
	18 002	3	← 2	$V_T x2^{-15}$		
	10 F0F		M V_T			
	$4 F0L	4	R B^*		B^* x 10^{-5}	
	68 4J5		$X2^{-17}x10^5$	B^* x 2^{-17}		
	18 007	5	← 7	B^* x 2^{-10}		
	10 F0L		MB^*			
	$4 F10	6	R $\tan^2\theta$		$\tan^2\theta x10^{-5}$	
	68 4J5		$X2^{-17}x10^5$	$\tan^2\theta x2^{-7}$		
	18 009	7	← 9	$\tan^2\theta x2^{-8}$		
	10 F10		M $\tan^2\theta$			
	$4 F11	8	R X_R		X_R x 10^{-5}	
	68 4J4		$X2^{-20}x10^5$	X_R $x2^{-20}$		
	10 F11	9	M X_R			
	$4 F12		R Y_R		Y_R x 10^{-5}	
	68 4J4	K	$X2^{-20}x10^5$	Y_R x 2^{-20}		
	10 F12		M Y_R			
	$4 F13	$	R Z_R		Z_R x 10^{-5}	
	68 4J4		$X2^{-20}x10^5$	Z_R x 2^{-20}		
	10 F13	N	M Z_R			
	K4 F14		+ a_1			
	78 4J7	J	$\div 360x10^{-5}$			
	KN 59F		KN59F			
	$4 59L	F	R R.A.			
	$N 400		U^*sin cos			
	00 000	L	00 000			
	00 5K0		00 5K0			

ORDVAC Problem No.________

Date ________ Sheet ________

Seq.	CODE	ADDRESS	ORDER	R_1	R_2	Description
	N4 354	5$0	(+) TS4			
	10 354		M TS4	i + 1 → i		
	04 4JI	1	(-)16 $x2^{-10}$			
	40 5$5		C' 5$5			
	K4 5KF	2	+ 5KF			
	N4 00N		(+) 2^{-39}			
	50 5KF	3	E' 5KF			
	K4 5KL		+ 5KL			
	N4 00N	4	(+) 2^{-19}			
	90 5KL		E 5KL			
	14 5KF	5	U' 5KF			
	K4 4F3		+ Add Σ			
	50 5KF	6	E' 5KF			
	K4 4F5		+ Add P_o			
	90 5KL	7	E 5KL			
	30 354		oMTS4	o → i		
	$4 F25	8	R X_H		$X_H \times 10^{-5}$	
	68 4J4		$X2^{-20}x10^5$	$X_H x2^{-20}$		
	10 F25	9	M X_H			
	28 012		+← 18			
	N4 354	K	(+) TS4			
	10 354		MTS4	i + → i		
	04 4J8	$	(-) 9 x 2^{-19}			
	40 5$F		C' 5$F			
	K4 5$8	N	+ 5$8			
	N4 00N		(+) 2^{-19}			
	90 5$8	J	E 5$8			
	90 5$9		E 5$9			
	N0 5$8	F	U 5$8			
	K4 4JF		+ HP Add	00F25	00F25	
	90 5$8	L	E 5$8			
	90 5$9		E 5$9			

Seq.	CODE	ADDRESS	ORDER	R_1	R_2	Description
	KN 5K1	5K0	A 5K1	$\cos^{a}{}_1$		
	10 371		M $\cos^{a}{}_1$			
	K4 F15	1	+ a_2			
	78 4J7		$\div 360\times10^{-5}$			
	KN 5K3	2	A 5K3			
	$4 5K3		R 5K3			
	$N 400	3	U* sin cos			
	00 5K4		00 5K4			
	KN 5K5	4	A 5K5	$\cos^{a}{}_2$		
	10 372		M $\cos^{a}{}_2$			
	K4 F16	5	+ a_3			
	78 4J7		$\div 360 \times 10^{-5}$			
	KN 5K7	6	A 5K7			
	$4 5K7		R 5K7			
	$N 400	7	U*sin cos			
	00 5K8		-5K8			
	KN 5K9	8	A 5K9	$\cos^{a}{}_3$		
	10 373		M $\cos_3$			
	K4 517	9	+ $\cos_4$			
	78 4J7		$\div 360\times10^{-5}$			
	KN 5K$	K	A 5K$			
	$4 4K$		R 5K$			
	SN 400	$	U* sin cos			
	00 4KN		-5KN			
	KN 5KJ	N	A 5KJ	$\cos{}^{a}{}_4$		
	10 374		M $\cos^{a}{}_4$			
	28 009	J	$\overline{+}\rightarrow 9$			
	10 30L		M b	$2^{-10}\rightarrow b$		
	30 354	F	oM TSA	$o \rightarrow i$		
	30 380		oM Σ_o			
	30 390	L	oM P_o			
	28 009		$+\rightarrow 9$			

Seq.	CODE	ADDRESS	ORDER	R_1	R_2	Description
		5N0	$+1^*$			
			M ρ_o			
		1	M 284			Initialize WRNP
			R B^*		$B^* \times 2^{-10}$	
		2	X P.c.1	$N_1^P \times 2^{-10}$		
			M N_1^P			
		3	R B^*		$B^x \times 2^{-10}$	
			X P.C.2			
		4	$(+)N_1^P$	$N_1^P+(P.C.2)\ B^* = N_2^P$		
			M $N2^P$			
		5	R ρ_o			Start next round here.
			Xu n		$n = 5^{13} \times 2^{-39}$	
		6	A 5N7			
			M ρ_o	n_1		
		7	+ 1/2			
			(-) P_o			
		8	← 1			
			MTSO			
		9	RTSO		$(1 - 2n_1)$	
			X 45/360			
		K	M E			
			R 5N$			
		$	U^*sin cos			
			00 5NN			
		N	MTSO	$\sin E \times 2^{-1}$	$\cos E \times 2^{-1}$	
			A 5NJ	$\cos E \times 2^{-1}$		
		J	M TS1			
			R ρ_o			
		F	Xu n			
			A 5NL			
		L	M ρ_o	n_2		
			+ 1/2			

ORDVAC Problem No.

Date

Sheet

Seq.	CODE	ADDRESS	ORDER	R_1	R_2	Description
	04 30N	5J0	(-) ρ_o			
	18 001		1	$(1 - 2n_2)$		
	10 352	1	MTS2			
	K4 30L		+b			
	04 30J	2	(-) N_1^P			
	20 5J$		C3J$			
	$4 352	3	RTS2		$(1 - 2n_2)$	
	68 4JK		X 45/360			
	10 314	4	M A			
	$4 5J5		R 5J5			
	$N 400	5	U^*sin cos			
	00 5J6		-5J6			
	10 352	6	M TS2	sinA x 2^{-1}	cos A x 2^{-1}	
	KN 5J7		A 5J7	cos A x 2^{-1}		
	10 353	7	M TS3			
	K4 F25		+ X'_H			
	10 363	8	Mx 4			
	K4 F26		+ Y'_H			
	10 364	9	M Y_H			
	K4 F27		+ Z'_H			
	10 365	K	M Z_H			
	N0 600		U Fuze			
	K4 30L	$	+b			
	04 30F		(-) N_2^P			
	20 5F7	N	C 5F7			
	F4 352		1+1 TS2	$11-2n_2 1$		
	04 00F	J	(-) 1/2			
	40 5JF		C' 5JF			
	14 5NJ	F	U' 5NJ			
	$4 352		R TS2			
	68 4J$	L	X 90/360			
	10 314		MA			

Date ________ ORDVAC Problem No. ________

Sheet ________

Seq.	CODE		ADDRESS	ORDER	R_1	R_2	Description
	$4	5F1	5F0	R 5F1			
	$N	400		U* sin cos			
	00	000	1	____			
	00	5F2		____ 5F2			
	10	352	2	M TS2	sin A x 2^{-1}	cos A x2^{-1}	
	KN	5F3		A 5F3	cos A x2^{-1}		
	10	353	3	M TS3			
	K4	F28		+ X_H^2			
	10	363	4	M X_H			
	K4	F29		+ Y_H^2			
	10	364	5	M Y_H			
	K4	F2K		+Z_H^2			
	10	365	6	M Z_H			
	N0	600		U Fuze			
	F4	352	7	1 H TS2	$\|l_1 + 2n_2\|$		
	04	00F		(-) 1/2			
	20	5F9	8	C 5F9			
	14	5NJ		U' 5NJ			
	$4	352	9	R TS2			
	68	4JN		X 180/360			
	10	314	K	MA			
	$4	5F$		R 5F$			
	$N	400	$	U* sin cos			
	00	5FN		- 5FN			
	10	352	N	M TS2	sinA x 2^{-1}	cos A x 2^{-1}	
	KN	5FJ		A 5FJ	cos A x 2^{-1}		
	10	353	J	M TS3			
	K4	F2$		+ X_H^3			
	10	363	F	M X_H			
	K4	F2N		+ Y_H^3			
	10	364	L	M Y_H			
	K4	F25		+t_H^3			

ORDVAC Problem No.

Date

Sheet

Seq.	CODE	ADDRESS	ORDER	R_1	R_2	Description
	10 365	5L0	M $\bar{z}_H$			
	N0 600		U Fuze			
80 000						
00 000						
80 001						
00 000						

ORDBG Form 1351-(R)
Rev 26 Mar 57

Army--APG, Md--O

FUZE, Guided Missile, Fixed Angle

ORDVAC Problem No. ________

Date ________

Sheet ________

Seq.	CODE	ADDRESS	ORDER	R_1	R_2	Description
Fuze 80 003	K4 350	600	+ TSO	sin $Ex2^{-1}$		
20 600	10 318		$M\lambda_3$			sin E $\rightarrow \lambda_3$
	\$4 352	1	R TS2		sin A x 2^{-1}	
	68 351		X TS1	cosEsinA$x2^{-2}$		
	18 001	2	$\leftarrow 1$			
	10 316		M λ_1			cosEsinA $\rightarrow \lambda_1$
	\$4 353	3	R TS3		cos A $x2^{-1}$	
	68 351		X TS1	cosEcosA$x2^{-2}$		
	18 001	4	$\leftarrow 1$			
	10 354		M TS4			
	24 354	5	-TS4			
	10 317		$M\lambda_2$			-cosEcosA$x2^{-1} \rightarrow \lambda_2$
	K4 353	6	+ TS3	cosA$x2^{-1}$		
	10 319		$M\rho_1$			cos A $\rightarrow a_1$
	K4 352	7	+ TS2	sinA$x2^{-1}$		
	10 31K		M ρ_2			sin A $\rightarrow a_2$
	K4 00K	8	+ θ			
	10 31\$		$M\rho_3$			$\theta \rightarrow a_3$
	\$4 352	9	R TS2		sinA$x2^{-1}$	
	68 350		X TS θ	sinEsinA$x2^{-2}$		
	18 001	K	1			
	10 354		MTS4			
	24 354	\$	-TS4			
	10 31N		M a_1			- sinAsinE $\rightarrow a_1$
	\$4 350	N	RTSO		sinE$x2^{-1}$	
	68 353		XTS3	cosAsinE$x2^{-2}$		
	18 001	J	$\leftarrow 1$			
	10 31J		M a_2			cosAsinE $\rightarrow a_2$
	K4 351	F	+ TS1	cosE$x2^{-1}$		
	10 31F		M a_3			cos E $\rightarrow a_3$
	24 317	L	- λ_2	cosEcosA$x2^{-1}$		
	10 31L		M l_m			cosEcosA $\rightarrow L_m$

ORDVAC Problem No. ____________

Date ____________ Sheet ____________

Seq.	CODE		ADDRESS	ORDER	R_1	R_2	Description
	24	352	610	-TS2	$-\sin A x 2^{-1}$		
	10	320		M m_M			$-\sin A \rightarrow m_M$
	$4	350	1	R TSO		$\sin E x 2^{-1}$	
	68	353		X TS3	$\cos A \sin E x 2^{-2}$		
	18	001	2	← 1			
	10	354		M TS4			
	24	354	3	- TS4			
	10	321		M n_M			$-\sin E \cos A \rightarrow n_M$
	$4	F0J	4	R V_M		$V_M x 2^{-15}$	
	68	F0J		X V_M	$V_M^2 x 2^{-30}$		
	18	005	5	← 5	$V_M^2 x 2^{-25}$		
	10	354		M TS4			
	$4	F0F	6	R V_T		$V_T x 2^{-15}$	
	68	F0F		X V_T	$V_T^2 x 2^{-30}$		
	18	005	7	← 5	$V_T^2 x 2^{-25}$		
	N4	354		(+) TS4	$(V_T^2 + V_M^2)$	$x 2^{-25}$	
	10	354	8	M TS4			
	$4	F0F		R V_T		$V_T x 2^{-15}$	
	68	F0J	9	X V_M	$V_T V_M x 2^{-30}$		
	10	355		M TS5			
	$4	355	K	R TS5		$V_T V_M x 2^{-30}$	
	68	31L		X lm	$\cos E \cos A V_T$	$V_M x 2^{-31}$	
	18	007	$	← 7	$2 \cos E \cos A$	$V_1 V_M x 2^{-25}$	
	N4	354		(+) TS4	$V_R^2 x 2^{-25}$		
	08	005	N	→ 5	$V_R^2 x 2^{-30}$		
	$4	61J		R 61J			
	$N	139	J	U* √			
	00	61F		-61F			
	10	336	F	M V_R	$V_R x 2^{-15}$		
	$4	F0F		R V_T		$V_T x 2^{-15}$	
	68	31L	L	X l_M	$\cos A \cos E V_T$	$x 2^{-16}$	
	18	001		← 1	$\cos A \cos E V_1$	$x 2^{-15}$	

ORDBG Form 1351-(R)
Rev 26 Mar 57

Army--APG, Md--O

Date ______________

ORDVAC Problem No. ________

Sheet ________

Seq.	CODE		ADDRESS	ORDER	R_1	R_2	Description
	N4	F0J	620	(+) V_M	$(V_T \cos E \cos A + V_M) \times 2^{-15}$		
	08	001		$\rightarrow 1$			
	78	336	1	$\div V_R$		$\frac{V_T \cos A \cos E + V_M}{V_R} \times 2^{-1}$	
	KN	622		A 622			
	10	322	2	M l''_M			$\frac{V_T \cos A \cos E + V_M}{V_R} \rightarrow l''_M$
	\$4	352		R TS2		$\sin A \times 2^{-1}$	
	68	F0F	3	X V_T	$V_T \sin A \times 2^{-16}$		
	78	336		$\div V_R$		$\frac{V_T \sin A}{V_R} \times 2^{-1}$	
	KN	625	4	A 625			
	10	354		MTS4			
	24	354	5	-TS4	$\frac{-V_T \sin A}{V_R} \times 2^{-1}$		
	10	323		M m''_M			$\frac{-V_T \sin A}{V_R} \rightarrow m''_M$
	\$4	31J	6	R α_2		$\cos A \sin E \times 2^{-1}$	
	68	F0F		X V_T	$V_T \cos A \sin E \times 2^{-1}$		
	78	336	7	$\div V_R$		$\frac{V_T \cos A \sin E}{V_R} \times 2^{-1}$	
	KN	628		A 628			
	10	354	8	M TS4			
	24	354		- TS4	$\frac{-V_T \cos A \sin E}{V_R} \times 2^{-1}$		
	10	324	9	M n''_M			$\frac{-V_T \cos A \sin E}{V_R} \rightarrow n''_M$
	\$4	F0J		R V_M			
	68	31L	K	X l_M	$V_M \cos E \cos A \times 2^{-16}$		
	18	001		$\leftarrow 1$			
	N4	F0F	\$	(+) V_T	$V_M \cos E \cos A + V_T$		
	08	001		$\rightarrow 1$			
	78	336	N	$\div V_R$		$\frac{V_M \cos E \cos A + V_T}{V_R} \times 2^{-1}$	
	KN	62J		A 62J			
	10	316	J	M m''_T			$\frac{V_M \cos E \cos A + V_T}{V_R} \rightarrow m''_T$
	\$4	316		R λ_1		$\sin E \times 2^{-1}$	
	68	F0J	F	X V_M	$V_M \sin E \times 2^{-16}$		
	78	336		$\div V_R$			
	KN	630	L	A 630	$\frac{V_M \sin E}{V_R} \times 2^{-1}$		
	10	354		M TS4			

Date ______________ ORDVAC Problem No. ______________

Sheet ______________

Seq.	CODE	ADDRESS	ORDER	R_1	R_2	Description
	24 354	630	-TS4	$-\frac{\sin E V_M}{V_R}$	$\times 2^{-1}$	
	10 345		M $1''_T$			$\frac{-V_M \sin E}{V_R} \rightarrow 1''_T$
	\$4 318	1	Rλ_3		$\cos E \sin A \times 2^{-1}$	
	68 F0J		X V_M	$\cos E \sin A V_M$	$\times 2^{-16}$	
	78 336	2	$\div V_R$			
	KN 633		A 633	$\frac{V_M \cos E \sin A}{V_R} \times 2^{-1}$		
	10 354	3	M TS4			
	24 354		- TS4	$\frac{-V_M \cos E \sin A}{V_R} \times 2^{-1}$		
	10 347	4	M n''_T			$\frac{-V_M \cos E \sin A}{V_R} \rightarrow n''_T$
	30 32L		oM alf			
	K4 4NL	5	+NRNKW			
	\$4 636		R 636			
	\$N 283	6	U*NRN			
	00 637		00 637			
	K4 J00	7	+X_i GP		Next GP	is picked up here.
	04 363		(-) X_H			
	10 328	8	M X_{GP}			
	K4 J01		+Yi_{GP}			
	04 364	9	(-) Y_H			
	10 329		M Y_{GP}			
	K4 J02	K	+ Zi_{GP}			
	04 365		(-) Z_H			
	10 32K	\$	M Z_{GP}			
	\$4 328		R X_{GP}		$X_{GP} \times 2^{-20}$	
	68 316	N	X λ_1	$\lambda_1 X_{GP} \times 2^{-21}$		
	10 350		MTSO			
	\$4 329	J	R Y_{GP}		$Y_{GP} \times 2^{-20}$	
	68 317		X λ_2	$X_2 Y_{GP} \times 2^{-21}$		
	N4 350	F	(+) TSO			
	10 350		M TSO			
	\$4 32K	L	R Z_{GP}		$Z_{GP} \times 2^{-20}$	
	68 318		X 3	$\lambda_3 Z_{GP} \times 2^{-21}$		

ORDBG Form 1351-(R)
Rev 26 Mar 57

Army--APG, Md--O

ORDVAC Problem No. ____________

Date ____________ Sheet ____________

Seq.	CODE	ADDRESS	ORDER	R_1	R_2	Description
	N4 350	640	(+) TSO	$\Delta\alpha_{iGP} x 2^{-21}$		
	18 001		← 1	$\Delta\alpha_{iGP} x 2^{-20}$		
	10 32$	1	M $\Delta\alpha_{iGP}$			
	$4 328		R X_{GP}		$X_{GP} x 2^{-20}$	
	68 319	2	X e_1	$e_1 X_{GP} x 2^{-21}$		
	10 350		MTSO			
	$4 329	3	R Y_{GP}		$Y_{GP} x 2^{-20}$	
	68 31K		X $\rho 2$	$\rho_2 Y_{GP} x 2^{-21}$		
	N4 350	4	(+) TSO			
	10 350		MTSO			
	$4 32K	5	R Z_{GP}		$Z_{GP} x 2^{-20}$	
	68 31$		X $\rho 3$	$\rho_3 Z_{GP} x 2^{-21}$		
	N4 350	6	(+) TSO	$\Delta\alpha_{2GP} + 2^{-21}$		
	18 001		← 1	$\Delta\alpha_{2GP} x 2^{-20}$		
	10 32N	7	M $\Delta\alpha 2_{GP}$			
	$4 328		R X_{GP}		$X \times 2^{-20}$	
	68 31N	8	X a1	$a_1 X \times 2^{-21}$		
	10 350		M TSO			
	$4 329	9	R Y_{GP}		$Y \times 2^{-20}$	
	68 31J		X a_2	$a 2^{Y} \times 2^{-21}$		
	N4 350	K	(+) TSO			
	10 350		MTSO			
	$4 32K	$	R Z_{GP}		$Z \times 2^{-20}$	
	68 31F		X a_3	$a_3 Z \times 2^{-21}$		
	N4 350	N	(+) TSO	$\Delta\alpha_{3GP} x 2^{-21}$		
	18 001		← 1	$\Delta\alpha_{3GP} x 2^{-20}$		
	10 32J	J	M $\Delta\alpha_{3GP}$			
	K4 323		+ m''_M	$m'' \times 2^{-1}$		
	08 001	F	→ 1	$m'' \times 2^{-2}$		
	78 322		÷ $1''_M$		$m''/\rho'' x\ 2^{-1}$	
	68 32$	L	X $\Delta\alpha_{1GP}$	$m''/1'' \Delta\alpha_{iGP} x$	2^{-21}	
	18 001		← 1			

ORDVAC Problem No.______

Date ______ Sheet ______

Seq.	CODE	ADDRESS	ORDER	R_1	R_2	Description
	10 350	650	MTSO	$m''/l''\Delta_{iGP}x2^{-20}$		
	K4 300		$+a'_2$	$a'_2 \times 2^{-20}$		
	N4 32N	1	$(+)\Delta l_{2GP}$	$(a'_2+\Delta a_{2GP})x2^{-20}$		
	04 350		(-) TSO	$A \times 2^{-20}$		
	10 337	2	M A			
	K4 324		$+n''_M$	$n'' \times 2^{-1}$		
	08 001	3	$\rightarrow 1$	$n''x\ 2^{-2}$		
	78 322		$\div l''_m$		$n''/l'' \times 2^{-1}$	
	68 32$	4	$X\Delta a_{iGP}$	$n''/l''\Delta a_{iGP}x2^{-21}$		
	18 001		$\leftarrow 1$			
	10 350	5	MTSO			
	K4 301		$+a'_3$	$a'_3 \times 2^{-20}$		
	N4 32J	6	$+\Delta a_{3GP}$	$(a'_3+\Delta a_{3GP})x2^{-20}$		
	04 350		(-) TSO			
	10 338	7	M B	$BX2^{-20}$		
	$4 322		$R\ l''_M$		$l''x\ 2^{-1}$	
	68 322	8	$X\ l''_M$	$l''^2 \times 2^{-2}$		
	10 350		MTSO			
	$4 350	9	RTSO		$l''^2 \times 2^{-2}$	
	68 F10		$X \tan^2\theta$	$l''^2\tan^2\theta x2^{-10}$		
	10 350	K	MTSO			
	$4 323		$R\ m''_M$		$m'' \times 2^{-1}$	
	68 323	$	$X\ m''_M$	$m''^2\ x2^{-2}$		
	08 008		$\rightarrow 8$			
	04 350	N	(-) TSO	$(m''^2 - l''^2 \tan^2\theta) \times 2^{-10}$		
	10 350		MTSO			
	$4 324	J	$R\ n''_M$		$n'' x\ 2^{-1}$	
	68 324		$X\ n''_M$	$n''^2 x\ 2^{-2}$		
	08 008	F	$\rightarrow 8$	$m''^2 + n''^2 - l''^2 \tan^2\theta) \times 2^{-10}$		
	N4 350		(+) TSO		$A \times 2^{-20}$	
	10 350	L	MTSO			
	$4 337		RA			

ORDVAC Problem No.

Date

Sheet

Seq.	CODE	ADDRESS	ORDER	R_1	R_2	Description
	68 323	660	X m''_M	$m''A \times 2^{-21}$		
	10 351		MTS1			
	$4 338	1	R B		$B \times 2^{-20}$	
	68 324		X n''_M	$n'' B \times 2^{-21}$		
	N4 351	2	(+) TS1			
	10 351		MTS1			
	$4 351	3	RTS1		$(m''A + n''B) \times 2^{-21}$	
	68 322		X l''_M	$l''(m''A + n''B) \times 2^{-22}$		
	78 350	4	TSO		$\frac{l''(m''A + n''B)}{m''^2 + n''^2 - l''^2} - m^2 \theta \times 2^{-12}$	
	KN 665		A 665	$b \times 2^{-12}$		
	18 002	5	← 2	$b \times 2^{-10}$		
	10 339		M b			
	K4 337	6	+ A	$A \times 2^{-20}$		
	18 00K		← 10	$A \times 2^{-10}$		
	10 351	7	MTS1			
	K4 338		+ B	$B \times 2^{-20}$		
	18 00K	8	←10	$B \times 2^{-10}$		
	10 352		MTS2			
	$4 351	9	RTS1		$A \times 2^{-10}$	
	68 351		XTS1	$A^2 \times 2^{-20}$		
	10 351	K	MTS1			
	$4 352		RTS2		$B \times 2^{-10}$	
	68 352	$	XTS2	$B^2 \times 2^{-20}$		
	N4 351		(+) TS1	$(A^2+B^2) \times 2^{-20}$		
	10 351	N	MTS1			
	$4 351		RTS1		$(A^2+B^2) \times 2^{-20}$	
	68 322	J	X l''_M	$l''(A^2+B^2) \times 2^{-21}$		
	10 351		MTS1			
	$4 351	F	RTS1		$l''(A^2+B^2) \times 2^{-21}$	
	68 322		X l''_M	$l''^2(A^2+B^2) \times 2^{-22}$		
	78 350	L	÷ TSO		$\frac{l''^2 (A^2+B^2)}{m''^2 + n''^2 - l''^2} \tan^2\theta \times 2^{-12}$	
	KN 670		A 670			

Date

ORDVAC Problem No.

Sheet

Seq.	CODE	ADDRESS	ORDER	R_1	R_2	Description
	18 002	670	← 2	$C \times 2^{-10}$		
	10 33K		M C			
	\$4 339	1	R b		$b \times 2^{-10}$	
	68 339		X b	$b^2 \times 2^{-20}$		
	10 350	2	MTSO			
	24 33K		-C	$-c \times 2^{-10}$		
	08 00K	3	→ 10	$-c \times 2^{-20}$		
	N4 350		(+) TSO	$(b^2-c) \times 2^{-20}$		
	20 675	4	C 675			
	N0 67F		U 67F			P/U another G.P.
	\$4 676	5	R 676			
	\$N 139		U* $\sqrt{}$			
	00 000	6	——			
	00 677		- 677			
	10 350	7	MTSO	$\sqrt{b^2-c} \times 2^{-10}$		
	24 339		-b	$-b \times 2^{-10}$		
	N4 350	8	(+) TSO	$(-b + \sqrt{b^2-c}) \times 2^{-10}$		
	40 679		C' 679			
	14 67K	9	U' 67K			
	24 339		-b	$-b \times 2^{-10}$		
	04 350	K	(-) TSO	$(-b-\sqrt{b^2-c}) \times 2^{-10}$		
	08 00K		→ 10	$\alpha_{iGP} \times 2^{-20}$		
	04 32\$	\$	(-) $\Delta\alpha_{iGP}$	$\alpha_{iF} \times 2^{-20}$		
	10 350		MTSO			
	04 32L	N	(-) α_{1F}	α_{if} target	so far	
	20 67F		C 67F			
	K4 350	J	+ TSO			
	10 32L		M α_{1F}	α_{iF} target	so far	
	28 012	F	↔ 18	1×2^{-19}		
	N4 456		(+) iGP			
	10 4F6	L	M iGP	$i + 1 \to i$		
	04 306		(-) G			

ORDVAC Problem No.

Date

Sheet

Seq.	CODE	ADDRESS	ORDER	R_1	R_2	Description
	40 685	680	C' 685			
	K4 637		+ 637			
	N4 4FN	1	(+) Add Inc.			
	90 637		E 637			
	K4 638	2	+ 638			
	N4 4FN		(+)Add Inc.			
	50 638	3	E' 638			
	K4 63K		+ 63K			
	N4 4FN	4	(+)Add Inc.			
	90 63K		E 63K			
	N0 637	5	U 637			
	30 4F6		oMiGP			
	K4 4FJ	6	+GP Add			Initialize G. P.
	90 637		E 637			
	N4 00N	7	(+) 00N			Pick up for next
	50 638		E' 638			
	N4 00N	8	(+) 00N			
	90 63K		E 63K			
	K4 32L	9	+ a_{1F}	$a_{1F} \times 2^{-20}$		Largest a_{1F}
	N4 302		(+) ϵ	$a_{1F} + \epsilon$		
	10 350	K	MTSO			
	$4 336		R V_R		$V_R \times 2^{-15}$	
	68 322	$	X $1''_M$	$1''V_R \times 2^{-16}$		
	10 351		MTS1			
	$4 351	N	RTS1		$1''V_R \times 2^{-16}$	
	68 F30		X D_t	$1''V_R D_t \times 2^{-16}$		
	08 004	J	$\rightarrow 4$			
	N4 350		(+) TSO	$a_{1\beta} \times 2^{-20}$		
	10 330	F	M a_{1B}			
	K4 323		+ m''_M	$m'' \times 2^{-1}$		
	08 001	L	$\rightarrow 1$	$m'' \times 2^{-2}$		
	78 322		$\div 1''_M$	$m''/1'' \times 2^{-1}$		

Seq.	CODE	ADDRESS	ORDER	R_1	R_2	Description
	68 330	690	X $\alpha_{i\beta}$	$\alpha_{1B}\ m''/1'' \times 2^{-2}$		
	18 001		← 1			
	N4 300	691	(+) α_2	$\alpha_{2B} \times 2^{-20}$		
	10 331		M α_{2B}			
	K4 324	2	+ n''_M	$n'' \times 2^{-1}$		
	08 001		→ 1	$n'' \times 2^{-2}$		
	78 322	3	÷ $1''_M$		$n''/1'' \times 2^{-1}$	
	68 330		X α_{1B}	$n''/1''\alpha_{1B} \times 2^{-21}$		
	18 001	4	← 1			
	N4 301		(+) α'_3	$\alpha_{2B} \times 2^{-20}$		
	10 332	5	M α_{3B}			
	$4 330		R α_{1B}		$\alpha_{1B} \times 2^{-20}$	
	68 316	6	X λ_1	$1\alpha_{1B} \times 2^{-21}$		
	10 350		MTSO			
	$4 331	7	R α_{2B}		α_{2B}	
	68 319		X ρ_1	$\rho\ 1\alpha_{2B} \times 2^{-21}$		
	N4 350	8	(+) TSO			
	10 350		MTSO			
	$4 332	9	R α_{3B}		α_{3B}	
	68 31N		X α_1	$\alpha_1\alpha_{3B} \times 2^{-21}$		
	N4 350	K	(+) TSO	$-X'_B \times 2^{-21}$		
	18 001		← 1			
	04 363	$	(-) X_H	$(-X_B' - X_H) \times 2^{-20}$		
	10 350		M TSO	$-X_B \times 2^{-20}$		
	24 350	N	- TSO	$X_B\ X_2^{-20}$		
	10 333		M X_B			
	$4 330	J	R α_{1B}		$\alpha_{1B} \times 2^{-20}$	
	68 317		X λ_2	$\lambda_2\alpha_{1B} \times 2^{-21}$		
	10 350	F	MTSO			
	$4 331		R α_{2B}		$\alpha_{2B} \times 2^{-20}$	
	68 31K	L	X ρ_2	$\rho_2\alpha_{2B} \times 2^{-21}$		
	N4 350		(+)TSO			

ORDVAC Problem No. ________

Date ________ Sheet ________

Seq.	CODE	ADDRESS	ORDER	R_1	R_2	Description
	10 350	6K0	M BO			
	$4 332		R α_{3B}		$\alpha_{3B} \times 2^{-20}$	
	68 31J	1	X α_2	$\alpha_2\alpha_{3B}x2^{-21}$		
	N4 350		(+) TSO			
	18 001	2	← 1	$-Y_B' \times 2^{-20}$		
	04 364		(-) Y_H	$-(Y'_B+Y_H) \times 2^{-20}$		
	10 350	3	MTSO	$-Y_B \times 2^{-20}$		
	24 350		-TSO			
	10 334	4	M Y_B			
	$4 330		R α_{1B}		$\alpha_{1B}x2^{-20}$	
	68 318	5	X λ_3	$\lambda_3\alpha_{1B}x2^{-21}$		
	10 350		MTSO			
	$4 331	6	R α_{2B}		$\alpha_{2B}x2^{-20}$	
	68 31$		X ρ_3	$\rho_3\alpha_{3B}x2^{-21}$		
	N4 350	7	(+) TSO			
	10 350		MTSO			
	$4 332	8	R α_{3B}		$\alpha_{3B}x2^{-20}$	
	68 31F		X α_3	$\alpha_3\alpha_{3B}x2^{-21}$		
	N4 350	9	(+) TSO	$-z_B' x2^{-21}$		
	18 001		← 1			
	04 365	K	(-) z u	$-(z_B'+z_H)$ =	$-z_Bx2^{-20}$	
	10 350		MTSO			
	24 350	$	-TSO			
	10 335		M z_B			
	K4 F24	N	+ Var.Num. Sent		-Yes Var. Num. + No Var. Num.	
	40 6KJ		C' 6KJ			
	N0 920	J	U Var. Num.			
	K4 4N6		+BKW1			
	$4 4N7	F	RBKW2			
	SN 1N9		U* Blast	Check External Blast		
	K4 4N8	L	+IBKW1	"Yes - External Blast"		
	$4 4N9		RIBKW2			

Date ______________ ORDVAC Problem No. ________

Sheet ________

Seq.	CODE	ADDRESS	ORDER	R_1	R_2	Description
	$N 1N9	6$0	U*Blast	Check	Internal Blast	
	00 000			(If Internal	Blast go to	Frag.)
	K4 4NJ	1	+PKW1	No External or Internal Blast		
	$4 4NF		R PKW2			
	$N 205	2	U*PERF			
	00 000					
	34 6$5	3	oU' 6$5	Perf -No Debris		
	00 000					
	30 38K	4	oM P_{PERF}	Neither		
	30 38$		oM P_{Debris}			
	N0 700	5	U Frag			
	10 38$		M P_{Debris}			
	K4 00L	6	+ 1*			
	10 38K		M P_{PERF}			
	N0 700	7	U Frag			
	00 000					
	30 38K	8	oM P_{PERF}	Debris-No-	Perf	
	K4 00L		+1*			
	10 38$	9	M P_{Debris}			
	N0 700		U Frag			
80 000		K				
00 000						
80 001		$				
00 000						
		N				
		J				
		F				
		L				

Date ______ ORDVAC Problem No. ______

Sheet ______

Seq.	CODE	ADDRESS	ORDER	R_1	R_2	Description
Frag	24 316	700	$-\lambda_1$			
80 003	10 325		M $1'_t$			$1'_T$
20 700	24 317	1	$-\lambda_2$			
	10 326		M m'_t			m'_T
	24 318	2	$-\lambda_3$			
	10 327		M n'_t			n'_T
	K4 334	3	$+ y_B$			
	10 32F		M y^*_B			
	K4 F11	4	$+X_R$	$X_R \times 2^{-20}$		
	04 333		(-) X_B	$(X_R - X_B) \times 2^{-20}$		
	10 350	5	MTSO			
	K4 F13		$+Z_R$	$Z_R \times 2^{-20}$		
	04 335	6	(-) Z_B	$(Z_R - Z_B) \times 2$		
	10 351		MTS1			
	$4 350	7	RTSO		$(X_R - X_B) \times 2^{-20}$	
	68 325		X $1'_t$	$1'_t (X_R - X_B)$	$\times 2^{-21}$	
	10 352	8	MTS2			
	$4 351		RTS1		$(Z_R - Z_B) \times 2^{-20}$	
	68 327	9	X n'_t	$n'_t (Z_R - Z_B)$	$\times 2^{-21}$	
	N4 352		+TS2	$A_2 \times 2^{-21}$		
	18 006	K	← 6	$A_2 \times 2^{-15}$		
	10 33$		M A_2			
	K4 350	$	+ TSO			Change scale of
	18 005		← 5			$(X_R - X_B)$ and
	10 350	N	MTSO			$(Z_R - Z_B)$
	K4 351		+TS1			to 2^{-15}
	18 005	J	← 5			
	10 351		MTS1			
	$4 350	F	RTSO		$(X_R - Y_B) \times 2^{-15}$	
	68 350		XTSO	$(X_R - X_B) \times 2^{-30}$		
	10 350	L	MTSO			
	$4 351		RTS1		$(Z_R - Z_B) \times 2^{-15}$	

ORDBG Form 1351-(R)
Rev 26 Mar 57

Army--APG, Md--O

Seq.	CODE	ADDRESS	ORDER	R_1	R_2	Description
	68 351	710	XTS1	$(z_R - z_B)^2 x2^{-30}$		
	N4 350		(+) TSO	$A_3 x2^{-30}$		
	10 33N	1	M A_3			
	K4 F12		+ y_R			
	04 32F	2	$-y^*_B$	$(y_R - y_B^*)x2^{-20}$		
	10 350		MTSO			
	$4 350	3	RTSO		$(y_R - y_B)x2^{-20}$	
	68 326		X m'_t	$m'_t\ (y_R - y'_B)\ x2^{-21}$		
	18 006	4	← 6			
	N4 33$		(+) A_2	$A_1 \times 2^{-15}$		
	10 33J	5	M A_1			
	K4 350		+ TSO	$(y_R - y_B^*)x2^{-20}$		
	18 005	6	← 5	$(y_R - y^*B)x2^{-5}$		
	10 350		MTSO			
	$4 350	7	RTSO		$(y_R - y^*_B)x2^{-15}$	
	68 350		XTSO	$(y_R - y_B^*)^2x2^{-30}$		
	N4 33N	8	(+) A_3	$D_1^2 x2^{-30}$		
	$4 719		R R.A.			
	SN 139	9	$U^*\sqrt{}$			
	00 71K		- R.A.			
	10 33F	K	M D_1	D_1x2^{-15}		
	K4 33J		+ A_1	A_1x2^{-15}		
	08 001	$	→ 1	A_1x2^{-16}		
	78 33F		D_1		$A_1/D_1\ x2^{-1}$	
	KN 71J	N	KN 71J	$C_1\ x2^{-1}$		
	10 350		M TSO			
	40 727	J	C' 727			
	04 373		(-)cosa_3	$c_1 - \cos a_3$		
	20 725	F	C 725			
	K4 350		+TSO			
	04 374	L	(-) cosa_4			
	40 722		C' 722			

ORDVAC Problem No.________

Date ________ Sheet ________

Seq.	CODE	ADDRESS	ORDER	R_1	R_2	Description
	K4 F1N	720	+ a_5			
	10 310		M a			
	K4 F09	1	+ $V_{o,5}$			
	10 350		M TSO			
	N0 731	2	U 731			check $V_o = O$
	K4 F1$		+ a_4			
	10 310	3	M a			
	K4 F08		+ $V_{o,4}$			
	10 350	4	MTSO			
	N0 731		U 731			check $V_o = O$
	K4 F1K	5	+ a_3			
	10 310		M a			
	K4 F07	6	+$V_{o,3}$			
	10 350		MTSO			
	N0 731	7	U 731			check $V_o = O$
	04 371		(-) cosa_1			
	20 72L	8	C 72L			
	K4 350		+ TSO			
	04 372	9	(-) cos$a$2			
	40 72N		C' 72N			
	K4 F1K	K	+ a_3			
	10 310		M a			
	K4 F07	$	+$V_{o,3}$			
	10 350		MTSO			
	N0 731	N	U 731			check $V_o = O$
	K4 F19		+ a_2			
	10 310	J	M a			
	K4 F06		+ $V_{o,2}$			
	10 350	F	MTSO			
	N0 731		U 731			check $V_o = O$
	K4 F18	L	+ a_1			
	10 310		M a			

Date ____________ ORDVAC Problem No. ________

Sheet ________

Seq.	CODE	ADDRESS	ORDER	R_1	R_2	Description
	K4 F05	730	$+V_{o,1}$			
	10 350		MTSO			
	24 350	1	-TSO			p/u non-zero
	40 733		C'733			V_o
	K4 350	2	+TSO			
	10 311		M V_o			
	N0 73J	3	U 73J			
	30 354		oMTS4			
	K4 737	4	+737			
	N4 354		(+)TS4			
	90 737	5	E 737			
	24 311		$-V_o$			
	20 737	6	C 737			
	N0 73K		U 73K			
	K4 F0K	7	$+V_{o,1}$			
	10 311		M V_o			
	K4 354	8	+TS4			
	N4 00N		(+) 00N			
	10 354	9	MTS4			
	N0 734		U 734			
	K4 73N	K	+ 73N			
	10 737		M 737			
	N0 73J	$	U 73J			
	00 000					
	K4 F05	N	$+V_{o,1}$			
	10 311		M V_o			
	$4 311	J	R V_o		$V_o \times 2^{-15}$	
	68 310		X a	$aV_o \times 2^{-15}$		
	10 350	F	MTSO			
	$4 310		R a		a	
	68 33F	L	XD_1	$aD_1 \times 2^{-15}$		
	10 351		MTS1			

ORDBG Form 1351-(R)
Rev 26 Mar 57

Army--APG, Md--O

Date ______________ ORDVAC Problem No. ______________

Sheet ______________

Seq.	CODE	ADDRESS	ORDER	R_1	R_2	Description
	04 4J6	740	$(-)10\times2^{-15}$			
	20 74K		C 74K			
	K4 351	1	+TS1			
	18 00K		← 10			
	$4 743	2	R 743			
	$N 24F		$U^{*}\ \rho_x$			
	00 000	3	——			
	00 744		-744			
	04 4J2	4	$(-)1\times2^{-15}$	$(\ ^{ax}-1)\times2^{-15}$		
	08 005		→ 5			
	78 350	5	TSO		$t^{*}\times 2^{-5}$	
	68 F0F		X V_t	$t^{*}V_t\times2^{-20}$		
	N4 334	6	(+) Y_B	$(t^{*}V_t+Y_B)\times$	2^{-20}	
	10 32F		M Y^{*}_B			
	28 012	7	+→ 18			
	N4 4F$		(+) C			
	10 4F$	8	MC	1 + c → c		
	04 4NN		(-) K			
	20 74$	9	C 74$			
	14 711		U' 711			
	K4 00L	K	+ 1*			
	N0 744		U 744			
	30 4F$	$	oM C			
	K4 32F		+ Y_B^{*}			
	10 334	N	M Y_B			
	N0 74J		U Target			
Target	K4 33L	J	+ No. Targets done (M)			
	04 304		(-) T			
	20 76J	F	C 76J			
	K4 33L		+ M			
	04 307	L	(-) P			
	40 750		C' 750			

Date ______________ ORDVAC Problem No. ______

Sheet ______

Seq.	CODE	ADDRESS	ORDER	R_1	R_2	Description
	N0 75F	750	U Pilot			
	04 308		(-) E			
	20 752	1	C 752			
	14 75L		U' Eng.			
	04 309	2	(-) N_B			
	40 753		C' 753			
	N0 761	3	U Bomb			
	04 30K		(-) F			
	20 755	4	C 755			
	14 762		U'Fuel Line			
		5				Space for six (6)
						more target types.
		6				
		7				
		8				
		9				
		K				
		$				
80 003		N				
20 75F						
Pilot	K4 4F7	J				
	10 350					
	N0 76F	F	+Pilot Av	Add		
Eng.	K4 4F8		MTSO			
		L	U 76F			
			+ Eng Av.	Add		

ORDVAC Problem No. ________

Date ________ Sheet ________

Seq.	CODE	ADDRESS	ORDER	R_1	R_2	Description
	10 350	760	MTSO			
	N0 76F		U 76F			
Bomb	K4 4F9	1	+Bomb Av. Add			
	10 350		M TSO			
	N0 76F	2	U 76F			
Fuel	K4 4FK		+ Fuel Line Av.			
	10 350	3	M TSO			
	N0 76F		U 76F			
		4				Space for six (6)
						more target types.
		5				
		6				
		7				
		8				
		9				
		K				
		$				
80 003		N				
20 76J						
	30 33L	J	oM M			
	N0 800		U Comb			
	K4 33L	F	+ M	M		
	18 001		← 1			
	N4 33L	L	(+) M			
	N4 4F4		(+) Tc Add			

ORDVAC Problem No.

Date Sheet

Seq.	CODE	ADDRESS	ORDER	R_1	R_2	Description
	90 773	770	E 773			
	N4 00N		(+) 2^{-19}			
	90 774	1	E 774			
	N4 00N		(+) 2^{-19}			
	90 775	2	E 775			
	10 351		MTS1			
	K4 000	3	+ (X_{TM})			
	10 360		M X_T			
	K4 000	4	+ (Y_{TM})			
	10 361		M Y_T			
	K4 000	5	+ (Z_{+m})			
	10 362		M Z_T			
	K4 4F5	6	$+P_o$ Add			
	N4 00N		(+) 00N			
	N4 33L	7	(+) M			
	10 351		MTS1			
	K4 360	8	+ X_T	$X_T \times 2^{-20}$		
	04 333		(-) X_B	$(X_T - X_B) \times 2^{-20}$		
	10 353	9	MTS3			
	$4 353		RTS3			
	68 325	K	X $1'_T$	$1'_T(X_T - X_B) \times 2^{-21}$		
	18 00K		$\leftarrow 10$			
	10 354	$	MTS4			
	K4 361		+ Y_B	$Y_T \times 2^{-20}$		
	04 334	N	(-) Y_B	$(Y_T - Y_B) \times 2^{-20}$		
	10 352		MTS2			
	$4 352	J	RTS2		$(Y_T - Y_B) \times 2^{-20}$	
	68 326		X m'_T	$m'_T(Y_T - Y_B) \times 2^{-21}$		
	18 00K	F	$\leftarrow 10$			
	N4 354		(+) TS4			
	10 354	L	MTS4			
	K4 362		+ Z_T	$Z_T \times 2^{-20}$		

ORDBG Form 1351-(R)
Rev 26 Mar 57

Army--APG, Md--O

ORDVAC Problem No. ____________

Date ____________ Sheet ____________

Seq.	CODE	ADDRESS	ORDER	R_1	R_2	Description
	04 335	780	(-) z_B	$(z_T - z_B) \times 2^{-20}$		
	10 355		M TS5			
	$4 355	1	R TS5		$(z_T - z_B) \times 2^{-20}$	
	68 327		X n'_T	$n'_T(z_T - z_B) \times 2^{-21}$		
	18 00K	2	← 10			
	N4 354		(+) TS4	$C_1 \times 2^{-11}$		
	10 342	3	M C1			
	K4 353		+ TS3			Re-scale
	18 00K	4	← 10			$(X_T - X_B)$, $(Y_T - Y_B)$
	10 353		MTS3			$(z_T - z_B)$ to be
	K4 352	5	+ TS2			scaled 2^{-10}
	18 00K		← 10			
	10 352	6	MTS2			
	K4 355		+ TS5			
	18 00K	7	← 10			
	10 355		M TS5			
	$4 353	8	R TS3		$(X_T - X_B) \times 2^{-10}$	
	68 353		XTS3	$(X_T - X_B) \times 2^{-20}$		
	10 353	9	MTS3			
	$4 352		RTS2		$(Y_T - Y_B) \times 2^{-10}$	
	68 352	K	XTS2	$(Y_T - Y_B)^2 \times 2^{-20}$		
	N4 353		(+) TS3			
	10 353	$	MTS3			
	$4 355		RTS5		$(z_T - z_B) \times 2^{-10}$	
	68 355	N	XTS5	$(z_T - z_B)^2$-	2^{-20}	
	N4 353		(+) TS3			
	10 353	J	MTS3	$D^2 \times 2^{-20}$		
	$4 78F		R 78F			
	$N 139	F	$U^*\sqrt{}$			
	00 78L		-78 L			
	10 343	L	M D	$D \times 2^{-10}$		
	K4 342		+ C_1	$C_1 \times 2^{-11}$		

ORDVAC Problem No.______

Date______ Sheet______

Seq.	CODE	ADDRESS	ORDER	R_1	R_2	Description
	78 343	790	÷ D		$C_{1/D}$	
	KN 791		A 791	$C_{1/D} \times 2^{-1}$		
	10 344	1	$M\cos{}^{V}M^{V}F$			
	20 7K2		C 7K2			
	04 373	2	$(-)\cos a_3$			
	40 79J		C' 79J			
	K4 344	3	$+\cos{}^{V}M^{V}F$			
	04 374		$-\cos a$			
	20 799	4	C 799			
	K4 F04		$+ N_5$			
	10 312	5	MN			
	K4 F09		$+ V_{o,5}$			
	10 311	6	$M V_o$			
	K4 F1N		$+ a_5$			
	10 310	7	M a			
	K4 F21		$+ m_5$			
	10 313	8	M m			
	14 7$1		U' 7$1			Check Shielding
	K4 F03	9	$+N_4$			
	10 312		M N			
	K4 F08	K	$+V_{o,4}$			
	10 311		$M V_o$			
	K4 F1$	$	$+a_4$			
	10 310		Ma			
	K4 F20	N	$+m_4$			
	10 313		M m			
	14 7$1	J	U' 7$1			Check Shielding
	K4 F02		$+ N_3$			
	10 312	F	M N			
	K4 F07		$+V_{o,3}$			
	10 311	L	$M V_o$			
	K4 F1K		$+ a_3$			

ORDBG Form 1351-(R)
Rev 26 Mar 57

Army--APG, Md--O

ORDVAC Problem No. ________

Date ________ Sheet ________

Seq.	CODE	ADDRESS	ORDER	R_1	R_2	Description
	10 310	7K0	M a			
	K4 F1L		+ m3			
	10 313	1	M m			
	14 7$1		U' 7$1			Check Shielding
	04 371	2	(-)cos a_1			
	40 7KJ		C' 7KJ			
	K4 344	3	+cos V_{MVF}			
	04 372		(-)cos a_2			
	20 7K9	4	C 7K9			
	K4 F02		$+N_3$			
	10 312	5	M N			
	K4 F07		$+ V_{o,3}$			
	10 311	6	M V_o			
	K4 F1K		+ a_3			
	10 310	7	M a			
	K4 F1L		+ m_3			
	10 313	8	M m			
	14 7$1		U' 7$1			Check Shielding
	K4 F01	9	$+N_2$			
	10 312		M N			
	K4 F06	K	$+ V_{o,2}$			
	10 311		M V_o			
	K4 F19	$	+ a2			
	10 310		M a			
	K4 F1F	N	+ m_2			
	10 313		M m			
	14 7$1	J	U' 7$1			Check Shielding
	K4 F00		$+N_1$			
	10 312	F	M N			
	K4 F05		$+V_{o,1}$			
	10 311	L	M V_o			
	K4 F18		$+a_1$			

ORDVAC Problem No.______

Date ______ Sheet ______

Seq.	CODE	ADDRESS	ORDER	R1	R2	Description
	10 310	7$0	M a			
	K4 F1J		+ m_1			
	10 313	1	M m			
	K4 4NK		+ $KW1			Check Shielding
	$4 4N$	2	R$KW2			
	SN 18L		U*Shield			
	34 7J6	3	oU' 7J6			Shielded
	00 000					
	$4 310	4	R a		a	
	68 343		X D	$aD\ x2^{-10}$		
	10 353	5	MTS3			
	04 4JJ		$(-)16x2^{-10}$			
	20 7$K	6	C 7$K			
	24 353		-TS3	-aD		
	18 005	7	← 5	$-aDx2^{-5}$		
	$4 7$8		R 7$8			
	$N 24F	8	$U^k\ \rho x$			
	00 7$9		- 7$9			
	10 353	9	MTS3	$\rho^{-aD}x2^{-15}$		
	14 7$K		U' 7SK			
	30 353	K	oM TS3			
	$4 353		R TS3		$\rho^{-aD}x2^{-15}$	
	68 311	$	X V_o	$V_o\ ^{-aD}x\ 2^{-30}$		
	18 00L		← 15	$\bar{v}\ x\ 2^{-15}$		
	10 353	N	MTS3			
	$4 353		RTS3		$\bar{v}\ \ x2^{-15}$	
	68 353	J	XTS3	$\bar{v}^2\ x\ 2^{-30}$		
	10 354		MTS4			
	$4 F0F	F	RV_T		$V_T\ x2^{-15}$	
	68 F0F		X V_T	$V_T^2\ x\ 2^{-30}$		
	N4 354	L	(+)TS4	$(V_T^2+\bar{v}^2)\ x$	2^{-30}	
	10 354		MTS4			

Date ____________ ORDVAC Problem No. ________ Sheet ________

Seq.	CODE	ADDRESS	ORDER	R_1	R_2	Description
	K4 352	7N0	+ TS2	$(Y_T - Y_B) \times 2^{-10}$		
	08 005		→ 5			
	78 343	1	÷ D		$\left(\frac{Y_T - Y_B}{D}\right) \times 2^{-20}$	
	68 F0F		X V_T	$\left(V_T \frac{(Y_T - Y_B)}{D}\right) \times 2^{-20}$		
	18 006	2	← 6			
	10 352		MTS2			
	$4 352	3	RTS2			
	68 353		XTS3	$\left[\bar{v} \frac{V_T \left(\frac{Y_T - Y_B}{D}\right)}{V_s^2 \times 2^{-30}}\right] \times 2^{-30}$		
	N4 354	4	+TS4			
	$4 7N5		R 7N5			
	$N 139	5	U* √			
	00 7N6		- 7N6			
	10 352	6	M TS2	$V_s \times 2^{-15}$		
	$4 352		R TS2		$V_s \times 2^{-15}$	
	68 313	7	X m	$(mv_s \times 10^{-4}) \times 2^{-15}$		
	18 005		← 5	$w \times 2^{-10}$		
	10 340	8	M w			
	K4 350		+ TSO			
	90 7NK	9	E 7NK			
	N0 7NK		U 7NK			
	N0 000	K	U (A_V)			
	00 000			Return from A_V to 7N$		
	K4 341	$	+ A_V	$Av \times 2^{-15}$		
	78 343		÷ D		$Av/D \times 2^{-5}$	
	KN 7NJ	N	A 7NJ	$Av/D \times 2^{-5}$		
	08 00K		10	$Av/D \times 2^{-15}$		
	78 343	J	D		$Av/D^2 \times 2^{-5}$	
	68 312		XN	$N\, Av/D^2 \times 2^{-20}$		
	18 005	F	← 5			
	10 350		MTSO			
	04 4JL	L	(-)16x2-15			
	20 756		C 7J6			

Date ______ ORDVAC Problem No. ______

Sheet ______

Seq.	CODE	ADDRESS	ORDER	R_1	R_2	Description
	24 350	7J0	-TSO			
	18 00K		← 10	$-\frac{NA}{D^2} \times 2^{-5}$		
	$4 7J2	1	R 7J2			
	$N 24F		$U^* C^x$			
	00 000	2	———			
	00 7J3		__ 7J3			
	10 350	3	M TSO	$\rho - \frac{NA}{D^2} x 2^{-15}$		
	K4 4J2		$+ 1 \times 2^{-15}$			
	04 350	4	(-) TSO			
	18 00L		← 15			
	10 350	5	MTSO			
	N0 7J7		U 7J7			
	K4 00L	6	$+ 1^*$			
	10 350		M TSO			Shielded Return
	K4 351	7	+ TS1	Left Add =	$[D_K]$	
	90 7J9		E 7J9			
	10 351	8	M TS1			
	K4 350		+TSO			
	10 000	9	M $[P_K]$			
	28 012		+← 18			
	N4 33L	K	(+) M			
	10 33L		M_M			
	N0 74J	$	U 74J			
	00 000					
80 000		N				
00 000						
80 001		J				
00 000						
		F				
		L				

ORDVAC Problem No. ________

Date ________ Sheet ________

Seq.	CODE	ADDRESS	ORDER	R_1	R_2	Description
80 003	K4 30L	900	+b			
20 900	04 F0L		(-) B*			
	20 90K	1	C 90K			
	28 009		+→ 9			
	N4 30L	2	(+) b			
	10 30L		M b			
	30 351	3	oMTS1	o → i		
	30 380		oM P_o			
	28 009	4	+→ 9			
	N4 351		(+) TS1			
	10 351	5	MTS1	i + 1 → i		
	04 4JJ		(-)$16x2^{-10}$			
	40 908	6	C' 908			
	K4 903		+ 903			
	N4 00N	7	(+) 00N			
	50 903		E' 903			
	14 903	8	U' 903			
	K4 4F5		+P_o add			
	50 903	9	E' 903			
	N0 5N5		U 5N5			Start New Round
	30 350	K	oMTSO	o → i		
	K4 390		+ Σ_1	$\Sigma_1 \times 2^{-10}$		
	78 30L	$	÷ b		$\Sigma 1/b$	
	KN 90N		A 90N	$\Sigma 1/b$		
	10 390	N	M Σ_1			
	28 012		+→ 18			
	N4 350	J	(+) TSO			
	10 350		MTSO	i + 1 → i		
	04 4J8	F	(-) $9x2^{-19}$			
	20 912		C 912			
	K4 90K	L	+ 90K			
	N4 00J		(+) 00J			

ORDVAC Problem No.

Date

Sheet

Seq.	CODE	ADDRESS	ORDER	R_1	R_2	Description
	50 90K	910	E' 90K			
	18 014		20			
	90 90N	1	E 90N			
	14 90K		U' 90K			
	K4 4F3	2	+ Add Σ			
	50 90K		E' 90K			
	90 90N	3	E 90N			
	K4 4J0		+KWO			
	$4 915	4	R 915			
	$N 0K9		U*IBMO			
	00 000	5	00 000			Bring in new input
	00 52$		00 52$			
80 001		6				
00 500						
		7				
		8				
		9				
		K				
		$				
		N				
		J				
		F				
		L				

ORDBG Form 1351-(R)
Rev 26 Mar 57

Army--APG, Md--O

REFERENCES

1. Hastings, Cecil, Jr. "Approximation in Numerical Analysis Form (15)", The Rand Corporation.

2. King, F. G. "Lotto Method of Computing Kill Probabilities", Ballistic Research Laboratories Memorandum Report No. 530 (CONFIDENTIAL).

3. Lehmer, D. H. "Mathematical Methods in Large-Scale Computing Units", "Proceedings of a Second Symposium (1949) on Large-Scale Digital Calculating Machinery", Harvard University Press (1951).

4. Sacks, Stanley and King, F. G. "Single-Shot Probability of an A-Kill On the B-29 Type Bomber by Nike I", Ballistic Research Laboratories Memorandum Report No. 553 (CONFIDENTIAL).

5. Juncosa, M. L. and Young, D. M. "A Mathematical Formulation for ORDVAC Computation of the Probability of Kill of an Airplane by a Missile", Ballistic Research Laboratories Report No. 867.

6. Juncosa, M. L. "Random Number Generation of the BRL High-Speed Computing Machines", Ballistic Research Laboratories Report No. 855.

DISTRIBUTION LIST

No. of Copies	Organization
1	Chief of Ordnance Department of the Army Washington 25, D.C. Attn: ORDTB - Bal Sec
1	Commanding Officer Diamond Ordnance Fuze Laboratories Washington 25, D.C. Attn: ORDTL-012
1	Commanding Officer Diamond Ordnance Fuze Laboratories Washington 25, D.C. Attn: Mr. R. Hoff
10	Commander Armed Services Technical Information Agency Arlington Hall Station Arlington 12, Virginia Attn: TIPCR
3	Chief, Bureau of Naval Weapons Department of the Navy Washington 25, D.C. Attn: DIS-33
1	Commander U.S. Naval Weapons Laboratory Dahlgren, Virginia
1	Commander U.S. Naval Ordnance Test Station China Lake, California Attn: Technical Library
1	Commanding Officer U.S. Naval Air Development Center Johnsville, Pennsylvania Attn: NADC Library
1	Superintendent U.S. Naval Postgraduate School Monterey, California
1	Commanding Officer and Director U.S. Naval Training Device Center Office of Naval Research Port Washington, New York Attn: Technical Information Desk
2	Commander Naval Ordnance Laboratory White Oak Silver Spring 19, Maryland
2	Operations Evaluation Group Department of the Navy Washington 25, D.C.
1	Commander Air Research and Development Command Andrews Air Force Base Washington 25, D.C.
1	Chairman Joint Air Defense Board Ent Air Force Base Colorado Springs, Colorado
1	Commander Army Antiaircraft Command Ent Air Force Base Colorado Springs, Colorado
1	Commander Air Proving Ground Center Eglin Air Force Base, Florida Attn: Guided Missile Branch
1	Director Air University Library Maxwell Air Force Base, Alabama
3	Commander Wright Air Development Division Wright-Patterson Air Force Base Ohio

DISTRIBUTION LIST

No. of Copies	Organization
1	Commander Air Technical Intelligence Center Wright-Patterson Air Force Base Ohio Attn: ATIA
1	Director of Research and Development U.S. Air Force Washington 25, D.C. Attn: AFDRT
2	Deputy Chief of Staff, Development U.S. Air Force Washington 25, D.C. Attn: AFDRT - GW, Guidance and Weapons Division AFDRT - ER
1	Deputy Chief of Staff, Operations U.S. Air Force Washington 25, D.C. Attn: AFOOP-Assistant for Operations
1	Chief of Staff U.S. Air Force Washington 25, D.C. Attn: AFOAC-E/T
1	Commanding General U.S. Continental Army Command Fort Monroe, Virginia
2	President U.S. Army Air Defense Board Fort Bliss, Texas
1	Assistant Commandant U.S. Air Defense School Fort Bliss, Texas
2	Commanding Officer U.S. Army Air Defense Center Fort Bliss, Texas
3	Commanding General Army Rocket and Guided Missile Agency Redstone Arsenal, Alabama Attn: Technical Library ORDXR-RHH ORDXR-RHB
1	Commanding General White Sands Missile Range New Mexico
1	Commanding General Frankford Arsenal Philadelphia 37, Pennsylvania Attn: Library Branch, 0270, Building 40
1	Commanding Officer Picatinny Arsenal Dover, New Jersey Attn: Library
1	Commanding Officer U.S. Army Chemical Research and Development Laboratories Army Chemical Center, Maryland Attn: Technical Library
1	Chief Signal Officer Department of the Army Washington 25, D.C. Attn: SIGRD-6
1	Director, Operations Research Office Department of the Army 6935 Arlington Road Bethesda, Maryland Washington 14, D.C.

DISTRIBUTION LIST

No. of Copies	Organization
1	Director IDA/Weapons Systems Evaluation Group Room 1E880, The Pentagon Washington 25, D.C.
1	Director National Bureau of Standards 232 Dynamometer Building Washington 25, D.C. Attn: Chief, Ordnance Development Laboratory
2	Chief of Staff, U.S. Army Research and Development Washington 25, D.C. Attn: Director/Special Weapons Air Defense Division Director/Special Weapons Missiles and Space Division
2	Director of Defense Research and Engineering (OSD) Washington 25, D.C. Attn: Director/Guided Missiles Director/Ordnance
1	Armor Research Foundation Illinois Institute of Technology Center Chicago 16, Illinois
1	Bell Telephone Laboratories, Inc. Whippany, New Jersey
1	CONVAIR A Division of General Dynamics Corporation Pomona, California Attn: G. Goldshine
1	Cornell Aeronautical Laboratory, Inc. 4455 Genessee Street Buffalo 5, New York
1	Lockheed Aircraft Corporation Missiles and Space Division P.O. Box 504 Sunnyvale, California Attn: Lee Amaya
1	Raytheon Company Missile Systems Division Bedford, Massachusetts Attn: Mr. Isadore Siverman Head, Applied Math Section
1	Applied Physics Laboratory The Johns Hopkins University 8621 Georgia Avenue Silver Spring, Maryland
1	The Johns Hopkins University Institute for Cooperative Research 3506 Greenway Baltimore 18, Maryland Attn: Dr. E.R.C. Miles, Ballistic Analysis Laboratory
1	Stanford Research Institute Menlo Park, California
1	University of Chicago Institute for Air Weapons Research Chicago 37, Illinois Attn: Dr. W. Bartky
1	University of Michigan Willow Run Laboratories P.O. Box 2008 Ann Arbor, Michigan
1	Dr. Robert E. Shafer 2536 College Avenue Berkeley 4, California

AD Accession No. ____________ UNCLASSIFIED

Ballistic Research Laboratories, APG

A MATHEMATICAL FORMULATION FOR ORDVAC COMPUTATION OF THE SINGLE-SHOT KILL PROBABILITIES OF A GENERAL MISSILE VERSUS A GENERAL AIRCRAFT Anthony D. Stiegler

BRLM Report No. 1306 November 1960

Missiles -
Kill probabilities
Mathematical
analysis

DA Proj No. 5B03-06-002, OMSC No. 5010.11.812, ORD Proj No. TB3-0007
UNCLASSIFIED Report

This report is an up-dating of BRL Report No. 867. That report gives a description of the physical model and the random number generators used in this report.

The methods of BRL Report No. 867 have become inadequate for the solution of the problem with all the recent modifications and refinements and have been superseded by the methods discussed in this report.

The main body of the report is devoted to a mathematical discussion of the problem and appendices are included for the programming. The equations were formulated by Messrs. De Gray and Stubbs. The following assumptions were made: the missile and target are traveling in straight lines, the rear nape of the cone fuze pattern has been omitted, the azimuth and elevation angles are not necessarily standard for all missiles.

The discussion has been limited to the fixed-angle (cone-type) guided missile fuze, but another fuze (the proximity fuze) is being analyzed and will be reported upon in due course.

AD Accession No. ____________ UNCLASSIFIED

Ballistic Research Laboratories, APG

A MATHEMATICAL FORMULATION FOR ORDVAC COMPUTATION OF THE SINGLE-SHOT KILL PROBABILITIES OF A GENERAL MISSILE VERSUS A GENERAL AIRCRAFT Anthony D. Stiegler

BRLM Report No. 1306 November 1960

Missiles -
Kill probabilities
Mathematical
analysis

DA Proj No. 5B03-06-002, OMSC No. 5010.11.812, ORD Proj No. TB3-0007
UNCLASSIFIED Report

This report is an up-dating of BRL Report No. 867. That report gives a description of the physical model and the random number generators used in this report.

The methods of BRL Report No. 867 have become inadequate for the solution of the problem with all the recent modifications and refinements and have been superseded by the methods discussed in this report.

The main body of the report is devoted to a mathematical discussion of the problem and appendices are included for the programming. The equations were formulated by Messrs. De Gray and Stubbs. The following assumptions were made: the missile and target are traveling in straight lines, the rear nape of the cone fuze pattern has been omitted, the azimuth and elevation angles are not necessarily standard for all missiles.

The discussion has been limited to the fixed-angle (cone-type) guided missile fuze, but another fuze (the proximity fuze) is being analyzed and will be reported upon in due course.

AD Accession No. ____________ UNCLASSIFIED

Ballistic Research Laboratories, APG

A MATHEMATICAL FORMULATION FOR ORDVAC COMPUTATION OF THE SINGLE-SHOT KILL PROBABILITIES OF A GENERAL MISSILE VERSUS A GENERAL AIRCRAFT Anthony D. Stiegler

BRLM Report No. 1306 November 1960

Missiles -
Kill probabilities
Mathemical
analysis

DA Proj No. 5B03-06-002, OMSC No. 5010.11.812, ORD Proj No. TB3-0007
UNCLASSIFIED Report

This report is an up-dating of BRL Report No. 867. That report gives a description of the physical model and the random number generators used in this report.

The methods of BRL Report No. 867 have become inadequate for the solution of the problem with all the recent modifications and refinements and have been superseded by the methods discussed in this report.

The main body of the report is devoted to a mathematical discussion of the problem and appendices are included for the programming. The equations were formulated by Messrs. De Gray and Stubbs. The following assumptions were made: the missile and target are traveling in straight lines, the rear nape of the cone fuze pattern has been omitted, the azimuth and elevation angles are not necessarily standard for all missiles.

The discussion has been limited to the fixed-angle (cone-type) guided missile fuze, but another fuze (the proximity fuze) is being analyzed and will be reported upon in due course.

AD Accession No. ____________ UNCLASSIFIED

Ballistic Research Laboratories, APG

A MATHEMATICAL FORMULATION FOR ORDVAC COMPUTATION OF THE SINGLE-SHOT KILL PROBABILITIES OF A GENERAL MISSILE VERSUS A GENERAL AIRCRAFT Anthony D. Stiegler

BRLM Report No. 1306 November 1960

Missiles -
Kill probabilities
Mathematical
analysis

DA Proj No. 5B03-06-002, OMSC No. 5010.11.812, ORD Proj No. TB3-0007
UNCLASSIFIED Report

This report is an up-dating of BRL Report No. 867. That report gives a description of the physical model and the random number generators used in this report.

The methods of BRL Report No. 867 have become inadequate for the solution of the problem with all the recent modifications and refinements and have been superseded by the methods discussed in this report.

The main body of the report is devoted to a mathematical discussion of the problem and appendices are included for the programming. The equations were formulated by Messrs. De Gray and Stubbs. The following assumptions were made: the missile and target are traveling in straight lines, the rear nape of the cone fuze pattern has been omitted, the azimuth and elevation angles are not necessarily standard for all missiles.

The discussion has been limited to the fixed-angle (cone-type) guided missile fuze, but another fuze (the proximity fuze) is being analyzed and will be reported upon in due course.

Quality Assurance and OPSEC Review

462

This form is an approval record for ARL generated information to be presented or disseminated external to ARL. Note: Submit all manuscripts in electronic format or camera ready copy. See attached instructions. If more space is needed, use reverse of form (include block numbers).

Section I - *To be completed by lead ARL author or COR*

A. General Information: ☐ Presentation ☐ Publication ☐ Report ☐ Multimedia ☐ BAA ☐ SBIR ☐ Invention Disclosure

1. Today's Date: 17 December, 2012
2. Due Date: 31 January, 2013
3. Unclassified Title or Solicitation Number/Title: BRL-1306 A MATHEMATICAL FORMULATION FOR ORDVAC COMPUTATION OF THE SINGLE SHOT KILL PROBABILITIES OF

4. Author(s): (Last, First, MI):
4a. STIEGLER,ANTHONY D

Modern POC Clifford Yapp

4b. E-mail address: clifford.w.yapp.civ@mail.mil

5. Site: APG
Office Symbol: RD-SLB-S

6. Telephone Number: 410-278-1382

7. Invited: ☐ Yes ☐ No

8. Contract No.:
ARL COR:

9. Key Words: ORDVAC, probability kill, geometric approximation, computer history

10. Distribution Statement: Is manuscript subject to export control? ☐ Yes ☑ No

11. Check Appropriate Letter and Number(s). See instructions:
A ☑ B ☐ C ☐ D ☐ E ☐ F ☐ X ☐ 0 ☒ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11 ☐

12. Security Classification: Unclassified

B. Presentation ☐ Conference Presentation ☐ Notable Presentation ☐ Key Note Speaker ☐ Briefing

13. Conference / Meeting Name:

14. Conference / Meeting Location:

15. Conference / Meeting Date

16. Conference / Meeting is: ☐ Classified ☐ Open to General Public ☐ Unclassified / Controlled Access ☐ Other

17. For nonpublic meetings: Will foreign nationals be attending? ☐ Yes ☐ No ☐ Don't know

18. Countries and International Agreement(s) of Foreign Nationals:

C. Publication ☐ Abstract ☐ Book ☐ Book Chapter ☐ Conference Proceeding ☐ Refereed Journal Article ☐ Other

19. Material will be submitted for publication in:
Journal Title: Country:

D. Report ☑ TR ☐ MR ☐ TN ☐ CR ☐ SR

20. Project No.: 5B03-06-002

21. Period Covered (mm/yyyy): 11/1/60

22. Sponsoring Agency: Ballistic Research Laboratory

E. Multimedia ☐ Software ☑ Web ☐ Poster ☐ Video Clip ☐ Other

23. Location: DTIC Public Website - AD0249957

F. Author's Statement

24. All authors have concurred in the technical content and the sequence of authors. All authors have made a substantial contribution to the manuscript, and all authors who have made a substantial contribution are identified in Block 4.

ARL Lead Author or COR X Clifford Yapp Date 17 December, 2012

Section II - *Approval to be completed by designated individual*

G. Technical Review

25. Technical Reviewer Name X Clifford Yapp Technical Reviewer Signature Date 17 December, 2012

H. Technical Publications Editorial Review

26. Editor Name X Editor Signature Date

I. Supervisor Review

27. Supervisor Name X Stephanie Snead Supervisor Signature Date 18 Dec 2012

Section III - *To be completed by an ARL Trained Internal OPSEC Reviewer*

OPSEC Review Checklist

OPSEC POC: Complete and explain any positive responses in block 28.
Note: ARL must be the proponent of the proposed information for release.

1. Does this material contain Sensitive Information?	☐ YES	☒ NO
2. Does this information contain state-of-the-art, breakthrough technology?	☐ YES	☒ NO
3. Does the United States hold a significant lead time in this technology?	☐ YES	☒ NO
4. Does this information reveal aspects of reverse engineering?	☐ YES	☒ NO
5. Does this material reveal any security practices or procedures?	☐ YES	☒ NO
6. Would release of this information be of economic benefit to a foreign entity, adversary, or allow for the development of countermeasures to the system or technology?	☐ YES	☒ NO
7. Does this material contain:		
a. Any contract proposals, bids, and/or proprietary information?	☐ YES	☒ NO
b. Any information on inventions/patent application for which patent secrecy orders have been issued?	☐ YES	☒ NO
c. Any weapon systems/component test results?	☐ YES	☒ NO
d. Any ARL-originated studies or after action reports containing advice and recommendations?	☐ YES	☒ NO
e. Weakness and/or vulnerability information?	☐ YES	☒ NO
f. Any information on countermeasures?	☐ YES	☒ NO
g. Any fielding/test schedule information?	☐ YES	☒ NO
h. Any Force Protection, Homeland Defense (security) information?	☐ YES	☒ NO
i. Information on subjects of potential controversy among military services or other federal agencies?	☐ YES	☒ NO
j. Information on military applications in space, nuclear chemical or biological efforts: high energy laser information; particle beam technology; etc?	☐ YES	☒ NO
k. Contain information with foreign policy or foreign relations implications?	☐ YES	☒ NO
l. Does this information contain current ARL Essential Elements of Friendly Information (EEFI)?	☐ YES	☒ NO

J. Internal OPSEC Review

28. OPSEC Review Comments / Explanations / Continuations:

29. Internal OPSEC Approval Statement:

I, the undersigned, am aware of the adversary's interest in DoD publications and in the subject matter of this material and that, to the best of my knowledge, the net benefit of this release out weighs the potential damage to the essential security of all ARL, AMC, Army, or other DoD programs of which I am aware.

STEPHEN POLYAK — OPSEC Reviewer Name
x Stephen Polyak — OPSEC Reviewer Signature
Date 2 JAN 13

Section IV - *To be completed by designated individual.*

K. Security

30. Foreign Disclosure Office *(Limited distribution information for release to foreign nationals)*
FDO Reviewer Name — FDO Reviewer Signature X — Date — N/A: ☒

31. Classified Information:
Classified by/Derived from:
Declassified on date: — Security Manager X — Date — N/A: ☒

32. Foreign Intelligence Office *(Limited distribution information)*
FIO Reviewer Name — X FIO Reviewer Signature — Date — N/A: ☒

33. ARL OPSEC Officer *Material has been reviewed for OPSEC Policy and* ☒ **IS** / ☐ **IS NOT** *acceptable for public release.*
Comments:
ARL OPSEC Officer Name — X Erich W. Meyerhoff — ARL OPSEC Officer Signature — Date 1/9/13

L. Division Chief

34. The information contained in this material has received appropriate technical / editorial review and ☒ **IS** / ☐ **IS NOT** *acceptable for public release.*
Denise A. Jordan for Bob Bowen — Division Chief Name
X Denise A. J — Division Chief Signature
Date 2/3/13

M. Public Affairs Office

35. The information contained in this material has received appropriate technical / editorial review and ☒ **IS** / ☐ **IS NOT** *approved for public release.*
Joyce M. Conant — PAO Reviewer Name
X Joyce M. Conant — PAO Reviewer Signature
Date 1/10/13